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THREE-DIMENSIONAL (3-D) PLASTIC PART EXTRUSION AND CONDUCTIVE INK PRINTING FOR FLEXIBLE ELECTRONICS

Tracy D. Hudson and Carrie D. Hill
Weapons Sciences Directorate
Aviation and Missile Research, Development, and Engineering Center

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Processes for using a MakerBot Computer Numerical Control (CNC) machine and Fujifilm Dimatix Materials Printer (DMP) were developed to facilitate future research in integrating electronics into structural features. In this project, the concept of structural electronics, or structronics, was investigated. Structronics seek to build wiring and electrical interconnects directly into component structures to diminish the need for structural fasteners. A MakerBot Cupcake CNC was used to investigate the fabrication of plastic structures by printing, and a Fujifilm DMP was used to create flexible Printed Circuit Boards (PCBs). After developing processes to make these machines easier to use, others in the lab will be able to utilize them to develop structures with integrated electronics.

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I. INTRODUCTION

In this project, the concept of structural electronics, or structronics, was investigated. Structronics seek to build wiring and electrical interconnects directly into component structures to diminish the need for structural fasteners. A MakerBot Cupcake Computer Numerical Control (CNC) [1] was used to investigate the fabrication of plastic structures by printing, and a Fujifilm Dimatix Materials Printer (DMP) [2] was used to create flexible Printed Circuit Boards (PCBs). After developing processes to make these machines easier to use, others in the lab will be able to utilize them to develop structures with integrated electronics.

II. MAKERBOT CUPCAKE CNC

The MakerBot Cupcake CNC (shown in Figure 1) is a Three-Dimensional (3-D) printer sized and priced for use by hobbyists. It is used to print plastic models of objects drawn using a 3-D Computer-Assisted Design (CAD) program. This machine is of interest to the structronics project because it provides the ability to prototype a design very cheaply without leaving the lab. The processes developed for using the MakerBot are essential to the continuation of the lab's work of developing in-house prototypes with integrated electronics.

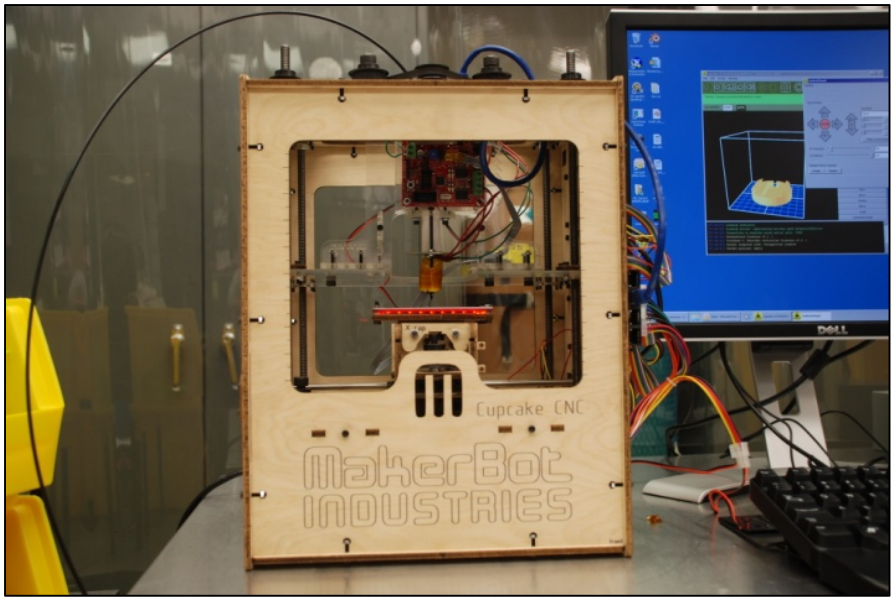

Figure 1. The MakerBot Cupcake CNC Uses GCode Machine Code

The printer works by slicing each model into layers, working from the top of the object to be printed to the bottom of the object to be printed. Then, it uses the layers to generate GCode, which is a machine code that tells the machine where it needs to deposit plastic on the build platform to print the object layer-by-layer. After generating GCode, the build process can be executed directly from the computer used to slice the model, or by saving the file to a Secure Digital (SD) card, it can be executed with no computer connected to the machine. During the build process, Acrylonitrile Butadiene Styrene (ABS) filament is pushed through a nozzle heated to 220 °C in much the same way as a hot glue gun is used to extrude glue. The extruder travels along the path defined by the GCode, leaving behind plastic to build the desired model.

All models from this investigation are found on the Thingiverse web site [3]. Thingiverse is a site created by MakerBot Industries, where MakerBot operators can publish their models and the files necessary to print copies of their models. The design of models for printing was not an attainable goal for this investigation because the time required learning Blender (a 3-D modeling software) was too long to fit within the time limit of the Science and Engineering Apprenticeship Program (SEAP) experience. The models used were chosen to investigate four areas of capability with the MakerBot as follows:

- Maximum size of models
- Minimum feature size of models
- Hollow object printing
- Precision

A. Maximum Size of Models

The first test performed sought to determine the maximum size of a model printed with the MakerBot. The test used a standard 3-D printing test print called the Stanford bunny, as shown in Figure 2. The bunny is a model from a repository of 3-D scans made by Stanford University and measures 89.42 millimeters tall by 75.95 millimeters wide with a depth of 49.66 millimeters. Height was a limiting factor when printing this model because any attempt to make the object taller than 95 millimeters would be unsuccessful because the extrusion tool would collide with the top of the machine. The width of the object was also on the verge of being too wide for the machine to handle. All of the 3-D models are printed on a surface called a raft, which makes objects easier to remove from the printer and serves to prevent failure of an entire print if Z-axis misaligns during printing. Objects wider than 85 millimeters cannot be printed because the raft will not fit on the build platform. While the object size is limited for each print, it is possible to divide objects into several smaller prints and put them together with adhesive or design the parts to snap together.

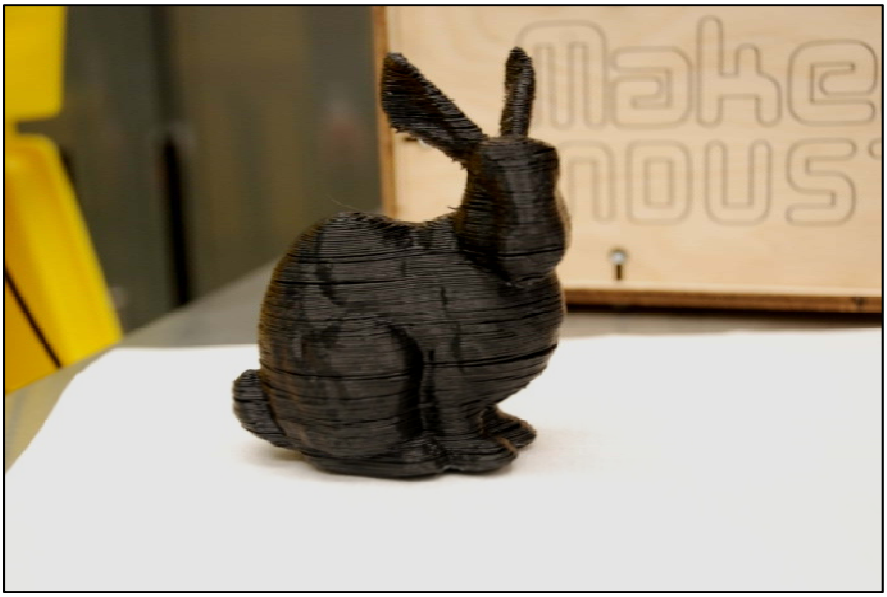

Figure 2. Stanford Bunny Model

B. Minimum Feature Size of Models

The second test performed was to show the minimum feature size achievable on a plastic model made on the MakerBot. The test used a small figure of a National Aeronautics and space Administration (NASA) space shuttle called a space orbiter, as shown in Figure 3. It measures 52.45-by-54.48-by-16.11 millimeters. The model shows the minimum feature size attainable on the MakerBot with its three thin wings. The wings measured only 2.57 millimeters at their thickest point, and the smallest of them is only 5.85 millimeters tall.

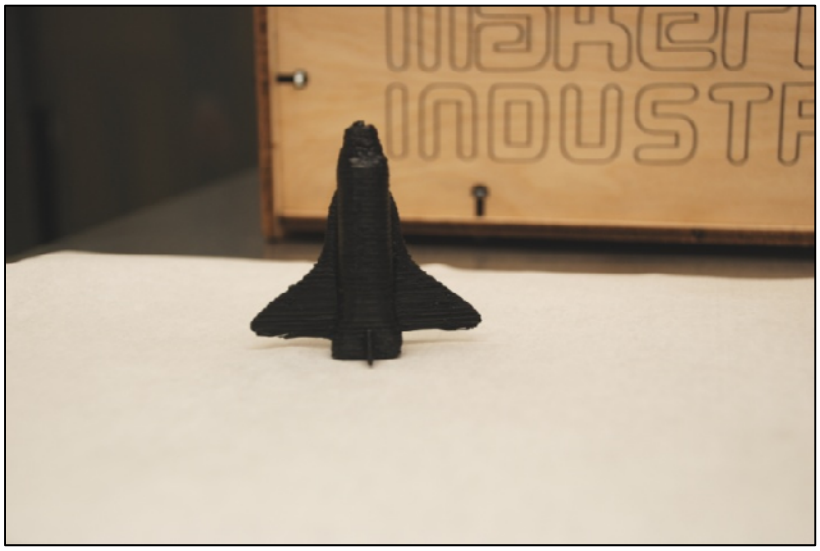

Figure 3. Space Shuttle Model

While features as small as these wings are attainable on the MakerBot, they are not always successful on the first try. Features that are small in one dimension must usually be larger in another dimension to compensate for the hot extruder on the device. For example, a structure that has a small width must have a broader depth so that the extruder does not stay in the same area for too long and burn the plastic.

The tests during this investigation were performed using a 3-millimeter ABS filament. MakerBot Industries also supplies a 1.75-millimeter ABS filament, which would make the achievement of a smaller minimum feature size possible. The material has been acquired, but it was too late to investigate in this time frame.

C. Hollow Object Printing

The third capability developed with the Makerbot is the ability to print objects with open spaces in their center. Hollow objects are difficult with 3-D printers because of the nature of an additive building process. It is impossible to deposit melted plastic into the air and have it stay in place, but objects can be made that are hollow given proper planning. One model that shows this is the hollow pyramid model, as shown in Figure 4. It measures 36.78-by-36.74-by-32.65 millimeters. By making the sides less than a 45-degree angle, the overhangs made by the printer assures that the upper parts of the model do not fall, which makes it possible to print models with open spaces.

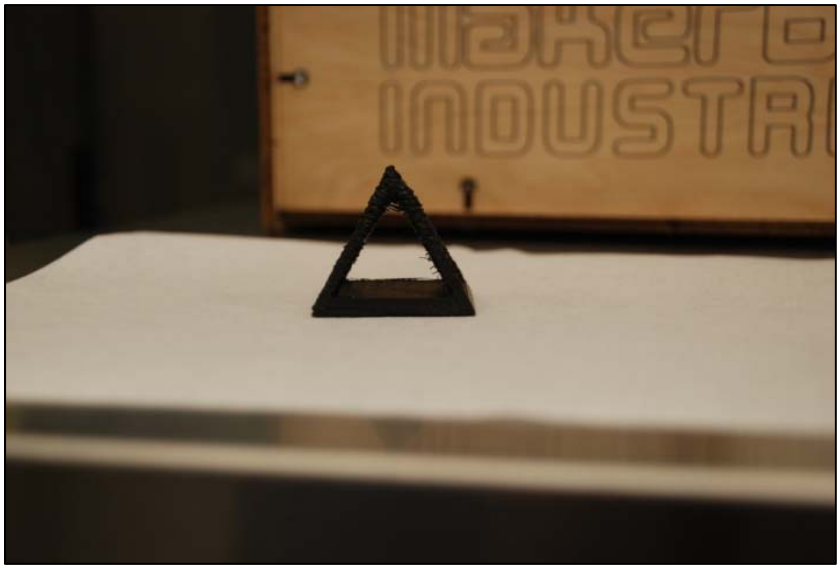

Figure 4. Hollow Pyramid Model

D. Precision of Mechanical Parts

The fourth capability of the MakerBot to be tested is precision printing. The goal of making printed parts that fit together is elusive. With the MakerBot, a product can be created that is broken down into several smaller parts for easier printing or to allow for moving parts, such as hinged arms. Two designs of very similar models were created to test this capability. The iris box model (shown in Figure 5) is a cylindrical box designed to open by twisting the top of the box, which should allow the shutters that seal the box to rotate outwards and reveal the contents of the box. The measurements for the model parts included the iris box lid (69.84-by-7.22 millimeters), shutters (29.7-by-34.53-by-4.57 millimeters), and pegs (5.15-by-27.54 millimeters).

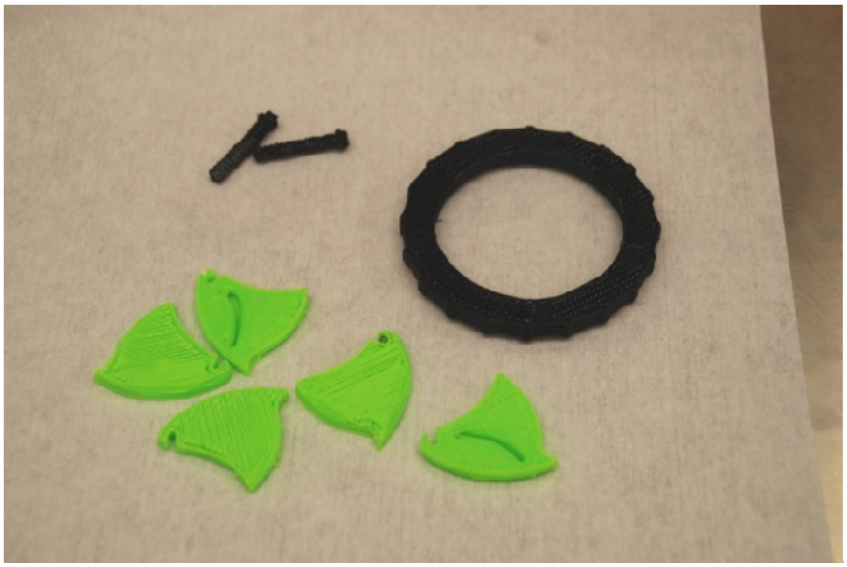

Figure 5. Iris Box Lid, Shutters, and Pegs

The top ring is printed first and set aside. Next, the five shutters that will compose the lid of the box are printed either individually or in an array, depending on how large the box is going to be. An array of pegs and a hollow cylindrical base are then printed and assembly should be possible. In these tests, however, the pegs printed by the MakerBot did not fit the rest of the parts. The problem with printing the pegs is that the hot extruder head stays in one area too long and causes plastic to melt post-extrusion. This causes the pegs to be irregularly shaped and not fit into the holes printed into the other parts of the model.

While the MakerBot is unable to print small objects like pegs that fit exactly where they are supposed to fit, it is capable of printing parts that fit together. A candy dispenser was produced that utilized dovetail joints to fit pieces together. The dispenser was divided into four prints—the base, the inside slider, the hopper, and the lid. The slider sits inside of the base with its handle protruding to the outside of the base. When the handle is pulled, the hole in the slider lines up with a hole in the bottom of the hopper, and a candy falls into the space. A spring pushes the slider back to its original position, sending the candy through the middle of the base and out of a hole in the bottom.

A new extruder and the next generation of MakerBot electronics have been ordered and partially assembled, but testing the new equipment did not fit within the time constraints of the project. The new extruder features a 0.4-millimeter nozzle and the ability to use the 1.75-millimeter filament. It also features a stepper motor to drive the extrusion. The new hardware is expected to give the MakerBot the ability to print with greater precision.

Appendix A provides a more detailed user instruction set for use of the Makerbot Cupcake CNC printer, Appendix B details the estimated time required to print each of the objects, and Appendix C provides an estimate of material and cost to extrude the previous plastic samples.

III. THE DMP

The DMP-2831 (shown in Figure 6) deposits fluidic materials on flexible substrates by using a piezoelectric inkjet cartridge. It can print patterns in a 200-by-300 millimeter area on substrates up to 25 millimeters thick. The platen features a vacuum to keep substrates stationary during printing. The temperature of the substrate is also controlled by the platen, which can be adjusted up to 60 ˚C. The printhead is a Micro-ElectroMechanical Systems (MEMS)-based cartridge that must be filled with the desired ink manually. The cartridges have a capacity of 1.5 milliliters, and each cartridge has 16 nozzles with drop sizes of 1 to 10 picoliters.

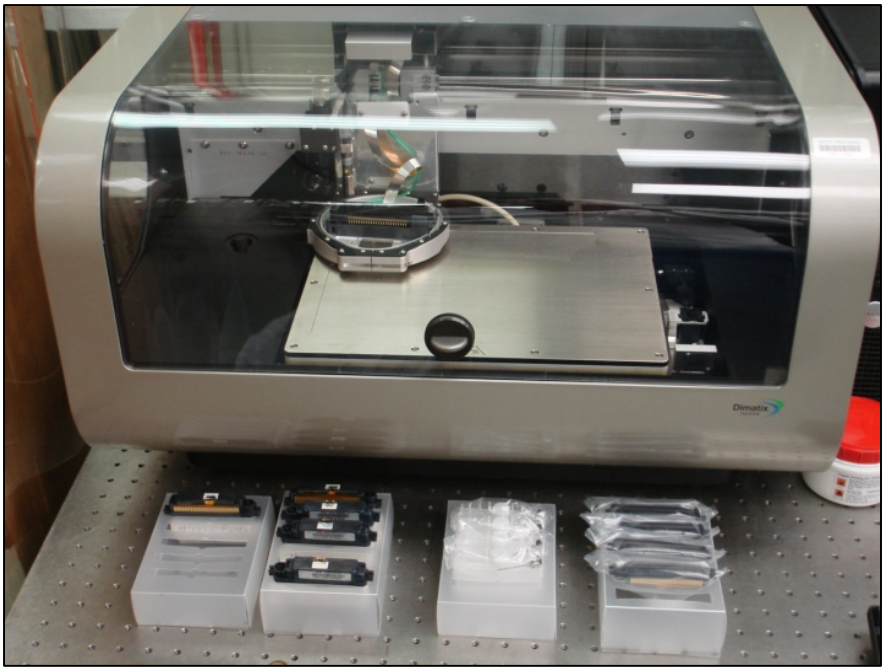

Figure 6. DMP-2831 Materials Printer

In this investigation, cartridges were filled with Dimatix model ink fluid, Intrinsiq copper, and Sigma-Aldrich silver inks. The Dimatix model ink fluid was used to develop a method for running the printer that would result in the most accurate prints.

The first step of the procedure was to fill a Dimatix cartridge with filtered ink. The cartridge was filled by using a syringe to extract 2 milliliters of ink from its storage bottle. The needle of the syringe was removed, and a 0.45-micron syringe filter was installed between the reservoir and the needle. The needle was then replaced, and the ink was filtered as it was injected into the cartridge. Finally, the cartridge was inserted into the machine and left stationary for 30 minutes to allow time for any air bubbles to be reabsorbed into the solution.

After the waiting period, the nozzles on the printhead were calibrated. Each nozzle on the DMP is an individually controlled piezoelectric device, and adjusting the voltage received by each of the 16 nozzles is key to uniform drop development. The voltages were adjusted using the Dimatix Drop Watcher program. The nozzles default to 16 volts each. This level was increased 1 volt at a time until drops began to form and fall from the nozzles. Then, each nozzle was adjusted individually with the goal being for all drops to move at the same speed. As the voltage applied to the nozzle was increased, the drops moved more quickly. As the voltage applied to the nozzle was decreased, the drops moved more slowly. All nozzles were calibrated using the eighth nozzle as the guide. After the nozzles were calibrated, Hewlett Packard (HP) photo paper was placed on the platen, and the patterns could be printed.

A. Dimatix Model Fluid

The Dimatix model fluid was the first ink tested. Black, non-conductive ink was used to learn how to use the DMP. The first test was done with all nozzles at 19 volts. This resulted in a blurred pattern with large, irregular ink drops due to an excess of ink being deposited. The second test was done after calibrating the nozzles so that each fired at the same time and at the same speed. Voltages sent to the nozzles after calibration ranged from 18.2 to 20 volts, as shown in Figure 7. Accuracy increased immediately in response to calibrating the nozzles. The pattern was clearer, and the drops deposited were more evenly dispersed; however, after calibrating the nozzles, they took longer to begin firing at the start of each line of printing. To correct this, a line was added to the left of all future patterns. In subsequent tests, this helped to prime the nozzles before printing the actual pattern.

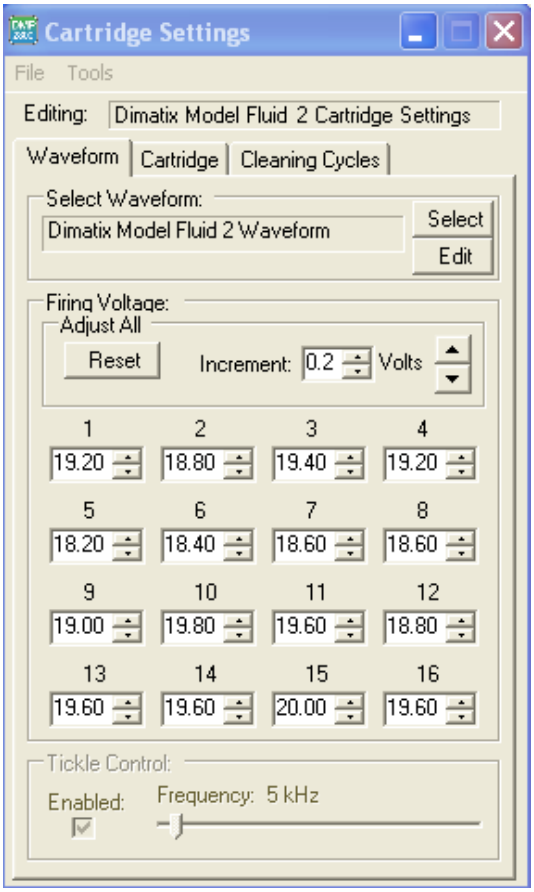

Figure 7. Cartridge Settings for Dimatix Model Fluid

B. Intrinsiq Copper Ink

The second ink tested was the Intrinsiq copper ink [4]. This was a conductive ink composed of nano copper, ethane, and butanol. In the first test with this ink, the cartridge could not be filled following the standard procedure because the ink would not pass through the .45-micron syringe filter and into the ink cartridge. The filter was removed in order to fill the cartridge. After being loaded into the printer, the cartridge remained stationary for 30 minutes to allow time for any air bubbles to be reabsorbed into the solution.

After the waiting period, drop formation was attempted using the Dimatix Drop Watcher software. No drops formed in response to 16 volts, so the voltage was increased in increments of 1 volt. While voltages were between 18 and 26 volts, drops formed but would not fall from the nozzle, as shown in Figure 8. Increasing the voltages further caused ink to gather around the opening of each nozzle.

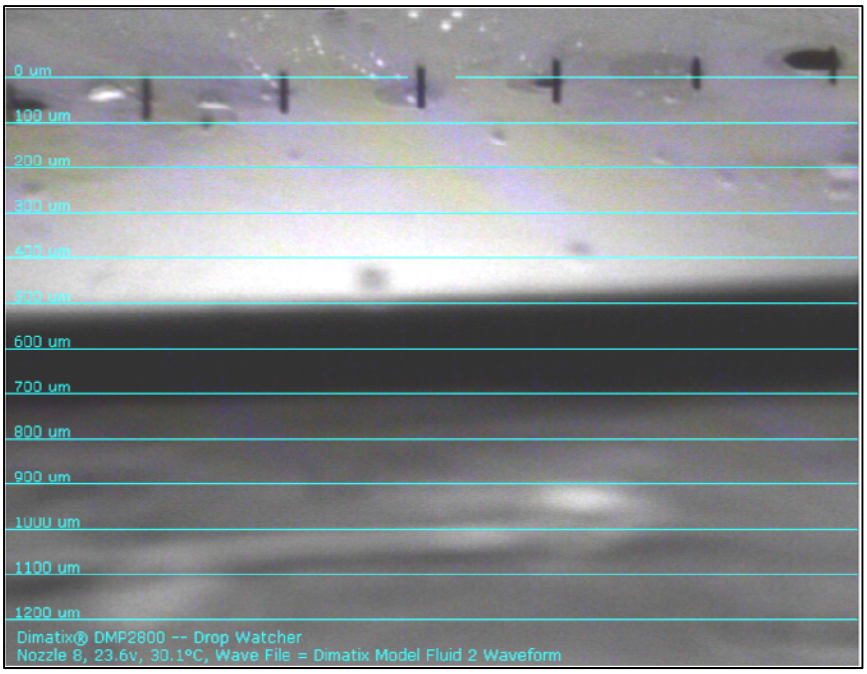

Figure 8. Dimatix Drop Watcher Image of Intrinsiq Copper Ink

One of the possibilities for the failure of drop formation with the Intrinsiq ink is that it was an unfiltered fluid. A second attempt at filtering the ink with a syringe and syringe filter was unsuccessful. After this attempt, the fluid was sent to another lab to be filtered. The ink passed through a .2-micron filter and was used in a second test. Another cartridge was filled with the ink and left to wait for 30 minutes. After that time, the Dimatix Drop Watcher software was used to produce ink drops before attempting to deposit it on the substrate. As with the first test, no drops formed in response to varying voltages sent to the nozzles.

The failure of the Intrinsiq ink to form drops that would allow for deposition on a substrate means that the liquid is too thick to pass through the nozzles. The surface tension of the fluid could also be a reason for the lack of success with this ink. High surface tension would account for the fact that droplets formed at the head of the nozzle but never actually fell. More tests should be performed after the ink has been successfully thinned.

C. Sigma Aldrich Silver Ink

The third ink tested was a conductive silver ink from Sigma Aldrich [5]. The silver ink was injected into a cartridge following the standard procedure and underwent the waiting period of 30 minutes before drop formation was attempted. Drop formation was partially successful. On 12 of the 16 nozzles, drop formation was a success. Nozzles 1, 5, 11, and 16 would not fire accurately at any voltage. For all printed tests, Nozzles 6 through 10 were the only nozzles used, as shown in Figure 9.

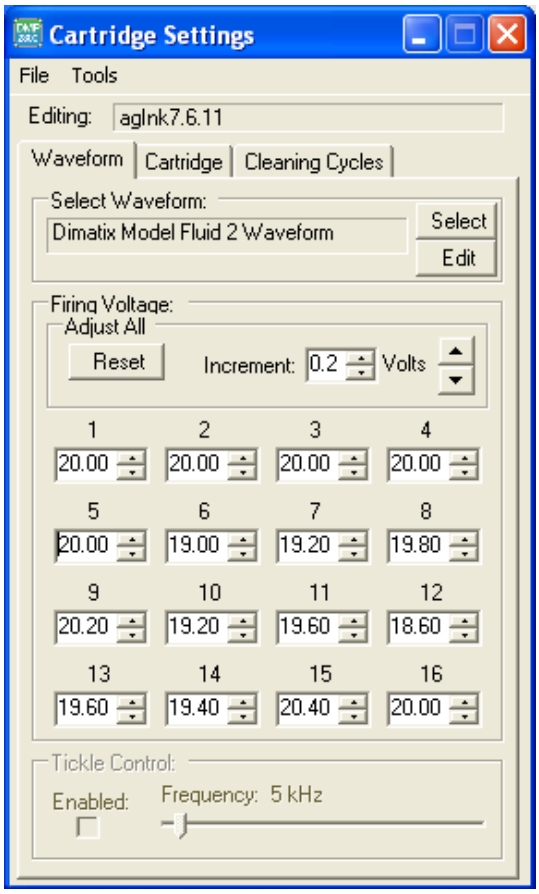

Figure 9. Cartridge Settings for Sigma Aldrich Silver Ink

Following successful drop formation, lines of varying sizes were printed. The goal was to measure the resistance of each line and determine how line width affects resistance with circuits printed with silver inks using the Dimatix printer. No data could be collected to show this, however, because the lines printed with the silver ink would not conduct electricity.

When examining the lines under a microscope, the reason silver ink does not conduct electricity becomes apparent—the Dimatix printer deposited the ink in bands. Thin bands of the ink are separated by spaces where there is no ink, resulting in the inability to allow a current to flow along the lines, as shown in Figure 10. This could have been caused by nozzles beginning to misfire after exiting the Dimatix Drop Watcher software. Altering the settings so that a cleaning cycle purges the nozzles during a print may help reduce the banding effect shown in this test.

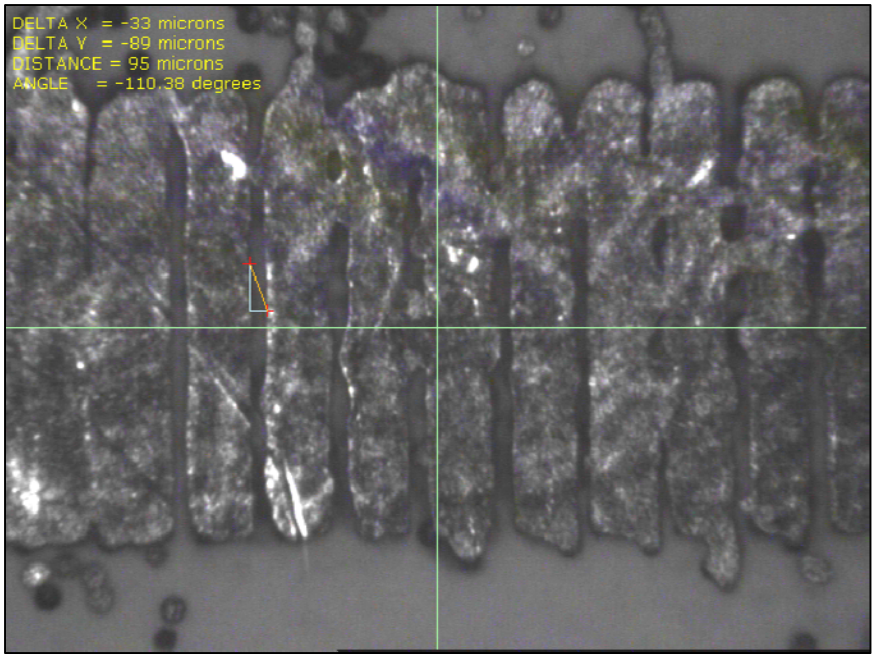

Figure 10. Photo of Bands of Silver Ink Separated by Empty Space

Although the lines printed for this test were not able to conduct electricity, other patterns printed with the Sigma Aldrich silver ink were able to conduct electricity. Lines, such as a spiral antenna, worked as they were supposed to and did not have the same problems with banding as the prints developed for the line-width resistance test, as shown in Figure 11. These patterns were printed prior to printing the pattern for the line-width test, suggesting that a nozzle had begun to malfunction over time.

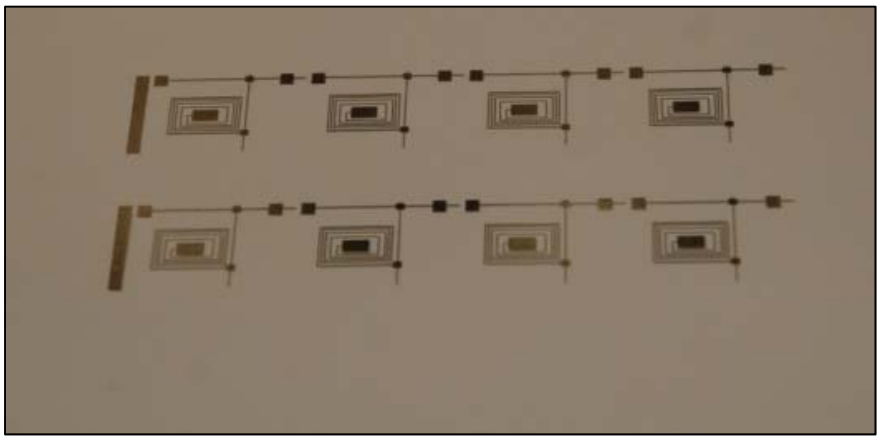

Figure 11. A Spiral Antenna Printed with Sigma Aldrich Silver Ink

Appendix D provides additional photographs of ink prints with the previous model fluid and silver inks. Appendixes E through G provide the Material Safety Data Sheets (MSDS) for model fluid and copper and silver inks used.

IV. CONCLUSION

With more testing, the integration of electronics into structural components is achievable with the lab's current equipment. The MakerBot Cupcake CNC can print prototypes, as long as they are designed such that no single print is larger than the area the extruder can travel. Metallic traces deposited on substrates by the Dimatix printer are viable for use as flexible PCBs and could be used to make a circuit board that goes around or inside of a prototype printed on the MakerBot.

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LIST OF ACRONYMS AND ABBREVIATIONS

3-D	Three-Dimensional
ABS	Acrylonitrile Butadiene Styrene
CAD	Computer-Assisted Design
CNC	Computer Numerical Control
DMP	Dimatix Materials Printer
HP	Hewlett Packard
MEMS	Micro-ElectroMechanical Systems
MSDS	Material Safety Data Sheet
NASA	National Aeronautics and Space Administration
PCB	Printed Circuit Board
SD	Secure Digital
SEAP	Science and Engineering Apprenticeship Program

APPENDIX A
HOW TO PRINT ON THE MAKERBOT CUPCAKE CNC

I. ACQUIRE A 3-D MODEL TO PRINT

A. Make it yourself

Using software such as Blender, Google Sketchup, or OpenScad, make your own Three-Dimensionsal (3-D) model, and export it as an .stl file.

B. Get it from Thingiverse

Go to www.thingiverse.com and find hundreds of models made by other MakerBot operators. These are excellent for testing your machine and fine-tuning your printing process.

II. MAKE YOUR MODEL PRINTABLE

Open your .stl file in ReplicatorG. Most likely, the model will not be centered on the platform or laying flat on the platform. The position and size of the model can be changed using the menus on the right of the program screen. Large models can also be rotated to fit on the platform should they need to be printed diagonally.

III. WARM UP THE MACHINE

Using the control panel in ReplicatorG, set the target temperature of the toolhead to 220 °C and the temperature of the heated build platform to 110 °C. After the toolhead has held a temperature of 220 °C for 10 minutes, run the extruder motor forward at 255 Pulse-Width Modulation (PWM) for 15 seconds to do a test extrusion.

Note: In ReplicatorG, the icon for the control panel is a pair of perpendicular lines terminating in arrows.

IV. GENERATE GCODE

At the right side of the ReplicatorG program screen is the Generate GCode button. After pressing this button, choose the *mk4 with heated build platform* user profile.

Note: This profile does not work as is. To use it, go to your newly generated GCode and replace the start.txt at the beginning with the text from hbp_settings.txt on the desktop.

V. POSITION THE BUILD PLATFORM

Before building and to avoid getting burned, move the build platform so that the extruder head is directly in the center of the platform by carefully holding the bottom of the build platform and moving it along the X- and Y-axes. Move the Z-axis to its starting position by grabbing the Z-axis belt at the rear of the machine's top and pulling it to the left. For fine adjustment, use the Z-axis adjustment wheel at the front of the machine. The extruder head should sit about 1 millimeter above the build platform.

VI. BEGIN THE BUILD

Press the *Build* button in the top left corner of the program screen. The extruder will move up and perform a test extrusion. When plastic is no longer coming out of the extruder, remove it with a razor blade or pair of tweezers and continue. The extruder will move down and begin printing the raft that your finished model will sit on. Then, it will print your model on top.

Note: The Z-axis usually does not move down far enough for the raft to be able to stick to the build platform. If the first line of the raft is not sticking, quickly but carefully use the fine adjustment knob to move the extruder down until plastic sticks to the platform.

VII. BE PATIENT

Printing with the MakerBot CupCake Computer Numerical Control (CNC) machine must be monitored at all times so that the print can be aborted if anything begins to go wrong. This machine is far from perfect. It was designed to be a hobby for people who like to fix things and problems should be expected. Common problems include the following:

- **The machine is running out of filament.** If the machine begins to run out of filament, cut a new piece of plastic and gently feed it into the machine directly after the filament being replaced. Do not allow any space between pieces of filament. Spacing will cause gaps in the printing that will cause other layers to sink into empty spaces and yield an unsuccessful print.

- **The extruder is dragging in the surface of the print.** Adjust the Z-axis by slowly turning the fine adjustment knob clockwise. Be careful not to move it up too far as this will cause flaws in the print. *Do not turn the knob the wrong direction! Doing this will cause the extruder to catch on the plastic and slip out of alignment.*

- **The filament begins to tie itself in knots.** If the knots can be removed, do so. If that is not possible, cut the filament before the beginning of the knotted section, get the filament back in order, and feed the end into the machine as if replacing the filament. If necessary, cut out the knotted section and feed the unknotted filament into the machine.

- **The Z-axis is not moving fast enough for smooth printing.** Apply oil to the threaded rods of the Z-axis, and be sure that the extruder platform is level. If the extruder platform is not level, lift the platform off the bolts it sits on, and move them up or down the threaded rods as needed.

APPENDIX B
TIME REQUIRED TO PRINT (ESTIMATED)

Model:	Time Required:
Stanford Bunny	2 hours, 5 minutes, 9 seconds
Shuttle	26 minutes, 14 seconds
Hollow Pyramid	22 minutes, 53 seconds
Iris Box Peg Array	6 minutes, 46 seconds
Iris Box Lid	46 minutes, 36 seconds
Iris Box Shutter Array	40 minutes, 43 seconds
Candy Dispenser Lid	39 minutes, 4 seconds
Candy Dispenser Hopper	1 hour, 19 minutes, 5 seconds
Candy Dispenser Slide	13 minutes, 50 seconds
Candy Dispenser Base	55 minutes, 49 seconds

APPENDIX C
AMOUNT OF MATERIAL USED AND COST

Model:	Material Used:	Cost: (Based on price of 1 kilogram roll)
Stanford Bunny	44.1g	$2.12
Shuttle	5.8g	$0.28
Hollow Pyramid	4.0g	$0.19
Iris Box Peg Array	1.8g	$0.09
Iris Box Lid	7.1g	$0.34
Iris Box Shutter Array	7.1g	$0.39
Candy Dispenser Lid	5.9g	$0.32
Candy Dispenser Hopper	22.4g	$1.08
Candy Dispenser Slide	3.4g	$0.19
Candy Dispenser Base	14.2g	$0.68

APPENDIX D
PRINTS FROM THE DMP-2831

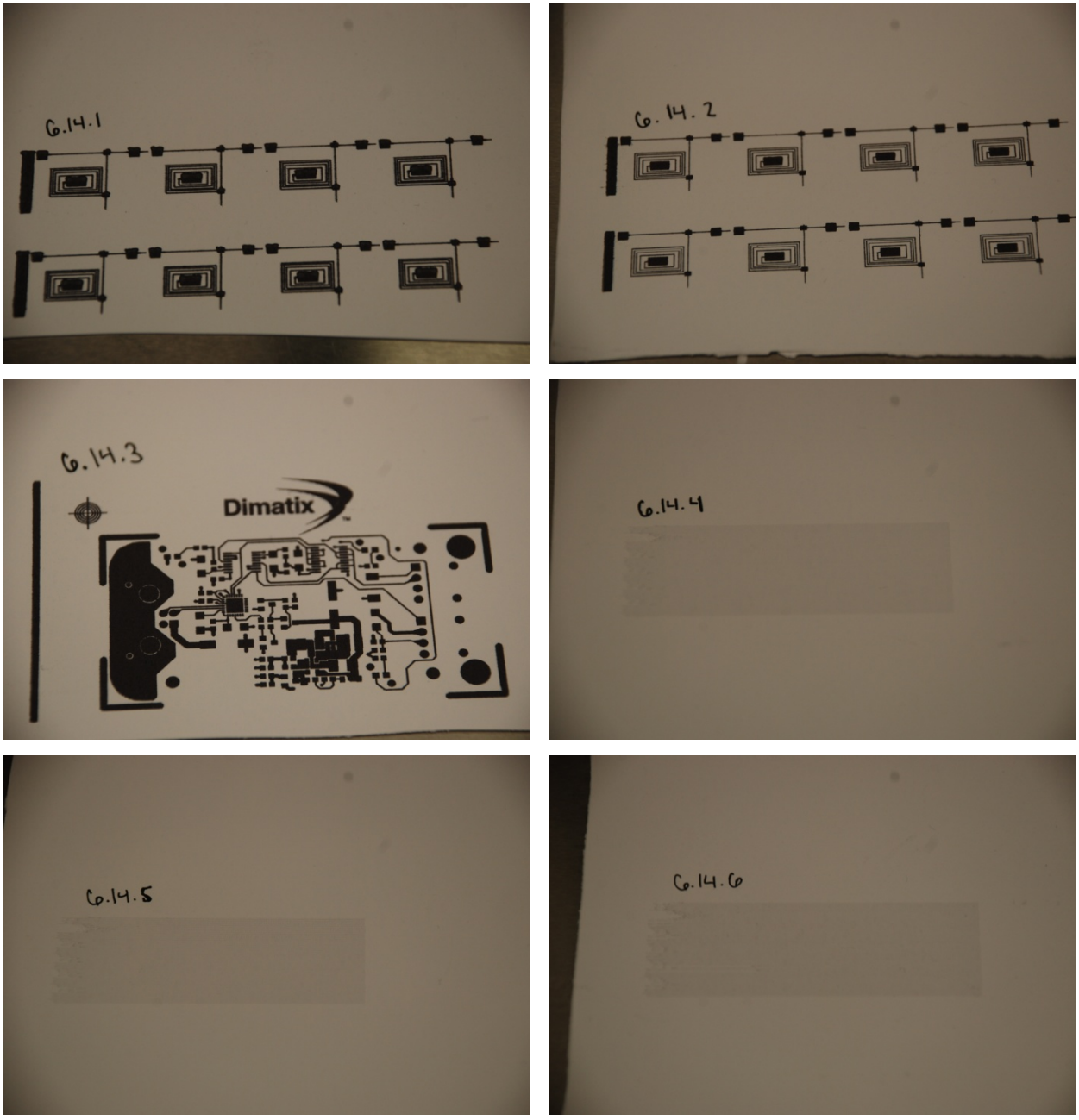


Figure D-1. Dimatix Model Fluid Prints

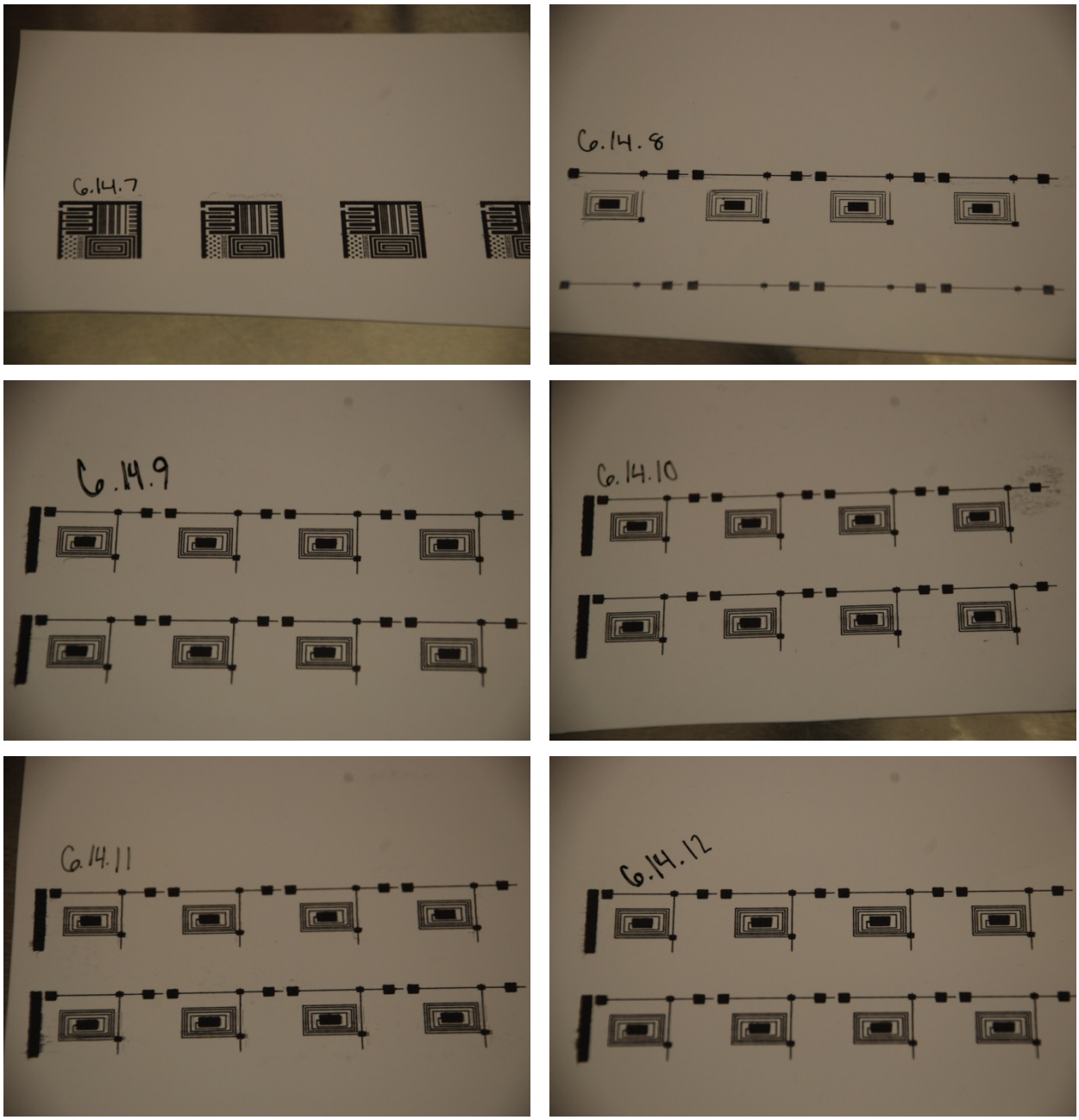


Figure D-1. Dimatix Model Fluid Prints (Concluded)

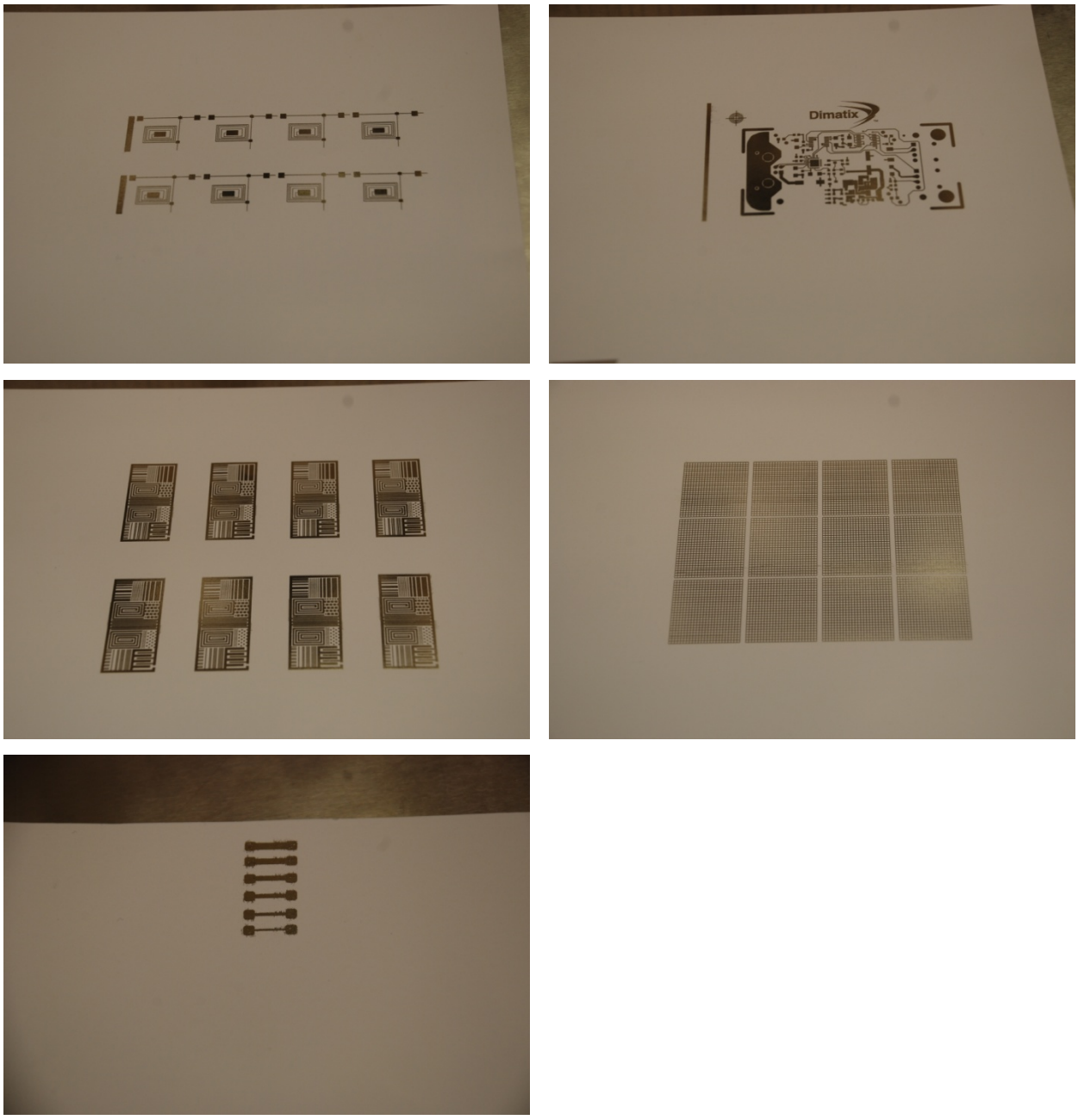


Figure D-2. Sigma Aldrich Silver Ink Prints

APPENDIX E
MSDS FOR DIMATIX MODEL FLUID

MATERIAL SAFETY DATA SHEET

Prepared to U.S. OSHA, CMA, ANSI, Canadian WHMIS, Australian WorkSafe, and European Union Standards

PART I *What is the material and what do I need to know in an emergency?*

1. PRODUCT IDENTIFICATION

TRADE NAME (AS LABELED):	**FUJIFILM Dimatix Model Fluid MFL-003**
CHEMICAL NAME/CLASS:	1,3-Propanediol-Based Fluid
SYNONYMS:	Not Applicable
PRODUCT USE:	Printing Operations
U.N. NUMBER:	None Allocated
U.N. DANGEROUS GOODS CLASS/SUBSIDIARY RISK:	None Allocated
HAZCHEM CODE (AUSTRALIA):	None Allocated
POISONS SCHEDULE NUMBER (AUSTRALIA):	None Allocated
SUPPLIER/MANUFACTURER'S NAME:	**PRISM INKS, INC.**
ADDRESS:	828 Ahwanee Ave. Sunnyvale, CA 94086, USA
INFORMATION PHONE:	01-408/436-6710
EMERGENCY PHONE:	(800) 424-9300 (**CHEMTREC**) INTERNATIONAL: 1-703-527-3887
SUPPLIER/IMPORTER'S NAME (AUSTRALIA):	
ADDRESS:	
EMERGENCY PHONE:	
BUSINESS PHONE:	
DATE OF PREPARATION:	Nov, 2008

2. COMPOSITION and INFORMATION ON INGREDIENTS

EU LABELING/CLASSIFICATION: This product does not meet the definition of any hazard class, as defined by the European Union Council Directives 67/548/EEC and 2001/59/EC. (See Section 15 for details on classification)

EU CLASSIFICATION: Not applicable.

EU RISK PHRASES: Not applicable.

CHEMICAL NAME	CAS #	EINECS #	% w/v	EU CLASSIFICATION FOR COMPONENTS
Butoxy Triglycol	143-22-6	205-592-6	1–5	HAZARD CLASSIFICATION: Xi [Irritant] RISK PHRASES: R: 41
Proprietary Aliphatic Amide	Proprietary		5–10	HAZARD CLASSIFICATION: Not applicable RISK PHRASES: Not applicable
Proprietary Aliphatic Triol	Proprietary		3–13	HAZARD CLASSIFICATION: Not applicable RISK PHRASES: Not applicable
Proprietary Black Colorant	Proprietary	Unlisted	7–13	HAZARD CLASSIFICATION: Not applicable RISK PHRASES: Not applicable
Proprietary Propanediol	Proprietary		30–50	HAZARD CLASSIFICATION: Not applicable RISK PHRASES: Not applicable
Water and other components each present in less than 1 percent concentration (0.1% concentration for potential carcinogens, reproductive toxins, respiratory tract sensitizers, and mutagens).			Balance	HAZARD CLASSIFICATION: Not applicable. RISK PHRASES: Not applicable.

See Section 15 for full EU classification information of product and components.

NOTE: ALL Canadian WHMIS required information is included in appropriate sections based on the ANSI Z400.1-1998 format. This product has been classified in accordance with the hazard criteria of the CPR and the MSDS contains all the information required by the CPR. The MSDS is also prepared to include all European Union required information under EU Directives.

3. HAZARD IDENTIFICATION

EU LABELING/CLASSIFICATION: This product does not meet the definition of any hazard class, as defined by the European Union Council Directives 67/548/EEC and 2001/59/EC. (See Section 15 for details on classification)

EU CLASSIFICATION: Not applicable.

EU RISK PHRASES: Not applicable.

3. HAZARD IDENTIFICATION (Continued)

EMERGENCY OVERVIEW: Product Description: This product is a black, liquid with a mild solvent odor. **Health Hazards:** The primary health hazard associated with this material is the potential for mild irritation of contaminated tissue. The fluid may stain skin, eyes, other contaminated tissue, and objects. **Flammability Hazards:** This material is not flammable. **Reactivity Hazards:** This material is not reactive. **Environmental Hazards:** This material may have adverse effects when released into the environment. **Emergency Recommendations:** Emergency responders must wear the personal protective equipment suitable for the situation to which they are responding.

SYMPTOMS OF OVEREXPOSURE BY ROUTE OF EXPOSURE: The most significant routes of occupational overexposure are inhalation and contact with skin and eyes. The symptoms of overexposure to this material, via route of entry, are described as follows:

INHALATION: This product does not normally present a significant inhalation hazard under anticipated circumstances of use. Inhalation of vapors, mists, or sprays of this material, may mildly irritate the nose, throat, and other tissues of the respiratory system. Symptoms of severe overexposure, especially as may occur in poorly ventilated areas, may include headache, coughing, irritation, and runny nose.

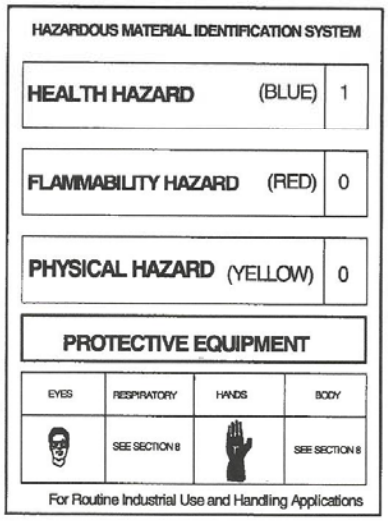
CONTACT WITH SKIN or EYES: Due to the colorant, skin contact may discolor contaminated areas. Skin contact may cause irritation or discomfort in sensitive individuals. Repeated or prolonged skin overexposure may cause dermatitis (dry, red skin). Eye contact with this material can mildly irritate the eyes, causing pain, tearing, and redness. Because the eye tissue may be stained, vision may be temporarily blurred.

SKIN ABSORPTION: The components of this product are not known to be absorbed through intact skin.

INGESTION: Though not anticipated to be a significant route of occupational exposure, ingestion of large quantities of this material may cause nausea, vomiting, diarrhea, and discoloration of the mouth, teeth, and tissues of the throat.

INJECTION: Accidental injection of this liquid (as may occur by a puncture with a contaminated object) will cause local pain, irritation, and redness.

HEALTH EFFECTS OR RISKS FROM EXPOSURE: An Explanation in **Lay Terms**. In the event of overexposure, the following symptoms may be observed:



Hazard Scale: **0** = Minimal **1** = Slight **2** = Mild **3** = Serious **4** = Severe ***** = Chronic hazard

ACUTE: The fluid may stain hair, skin, and other contaminated tissue. Acute exposure to this material via skin contact, eye contact, and inhalation may irritate contaminated tissue. Ingestion of large amounts may cause nausea, vomiting, and diarrhea.

CHRONIC: Chronic skin exposure to this product may cause dermatitis. Refer to Section 11 (Toxicology Information) for additional data.

TARGET ORGANS: ACUTE: Skin, eyes. CHRONIC: Skin.

PART II *What should I do if a hazardous situation occurs?*

4. FIRST-AID MEASURES

Contaminated individuals must be taken for medical attention if any adverse effect occurs. Rescuers should be taken for medical attention if necessary. Take a copy of the label and MSDS to health professional with victim.

SKIN EXPOSURE: If this material contaminates the skin, immediately begin decontamination with running water and soap. The minimum recommended flushing time is 15 minutes. Remove exposed or contaminated clothing, taking care not to contaminate eyes. The contaminated individual must seek medical attention if any adverse effect occurs.

EYE EXPOSURE: If vapors, sprays, or mists of this material enter the eyes, open the contaminated individual's eyes while under gently running water. Use sufficient force to open eyelids. Have the contaminated individual "roll" eyes. Minimum flushing is for 15 minutes. The contaminated individual must seek medical attention if any adverse effect occurs.

INHALATION: If vapors, sprays, or mists of this material are inhaled, remove the contaminated individual to fresh air. If necessary, remove or cover gross contamination to avoid exposure to rescuers. Seek medical attention if adverse effect occurs.

4. FIRST-AID MEASURES (Continued)

INGESTION: If this material is swallowed, CALL PHYSICIAN OR POISON CONTROL CENTER FOR MOST CURRENT INFORMATION. DO NOT INDUCE VOMITING, unless directed by medical personnel. Have victim rinse mouth with water if nscious. Never induce vomiting or give diluents (milk or water) to someone who is unconscious, having convulsions, or unable to swallow. If vomiting occurs, lean patient forward or place on left side (head-down position if possible) to maintain an open airway and prevent aspiration.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE: Pre-existing dermatitis and other skin disorders may be aggravated by prolonged overexposures to this material.

RECOMMENDATIONS TO PHYSICIANS: Treat symptoms and eliminate overexposure.

5. FIRE-FIGHTING MEASURES

FLASH POINT: Not flammable.

AUTOIGNITION TEMPERATURE: Not applicable.

FLAMMABLE LIMITS (in air by volume, %):

Lower (LEL): Not applicable.

Upper (UEL): Not applicable.

FIRE EXTINGUISHING MATERIALS:

Water Spray: YES (for cooling) Carbon Dioxide: YES

Foam: YES Dry Chemical: YES

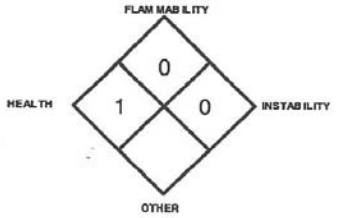
Halon: YES Other: Any "A" Class.

UNUSUAL FIRE AND EXPLOSION HAZARDS: When involved in a fire, this material may decompose and produce irritating vapors and toxic gases (e.g., carbon oxides and nitrogen oxides).

Explosion Sensitivity to Mechanical Impact: Not sensitive.

Explosion Sensitivity to Static Discharge: Not sensitive.

NFPA RATING



Hazard Scale: **0** = Minimal **1** = Slight **2** = Mild **3** = Serious **4** = Severe

SPECIAL FIRE-FIGHTING PROCEDURES: Incipient fire responders should wear eye protection. Structural firefighters must wear Self-Contained Breathing Apparatus and full protective equipment. Due to the presence of colorants, the runoff water from these products can discolor contaminated objects. If possible, prevent runoff water from entering storm drains, bodies of water, or other environmentally sensitive areas. If necessary, se fire-response equipment with soapy water before returning it to service.

6. ACCIDENTAL RELEASE MEASURES

SPILL AND LEAK RESPONSE: For incidental spills (e.g., less than 1 L of liquid from a bottle), wear rubber gloves, splash goggles, and appropriate body protection. Trained personnel following pre-planned procedures should handle non-incidental releases (e.g., 10 L of liquid leaking from a crate of several containers). In the event of a non-incidental spill, clear the area and protect people. The minimum personal protective equipment for response to a non-incidental spill is as follows: rubber gloves, rubber boots, face shield, and Tyvek suit. The minimum level of personal protective equipment for releases in which the level of oxygen is less than 19.5% or is unknown must be **Level B: triple-gloves (rubber gloves and nitrile gloves over latex gloves), chemical resistant suit and boots, hard hat, and Self-Contained Breathing Apparatus.** Absorb spilled liquid with polypads or other suitable absorbent materials. Rinse area thoroughly with soapy water. Decontaminate the area thoroughly. If necessary, discard all stained response equipment or rinse with soapy water before returning such equipment to service. Place all spill residue in an appropriate container and seal. Dispose of in accordance with applicable U.S. Federal, State, and local procedures or appropriate standards of Canada, Australia, or EU Member States (see Section 13, Disposal Considerations).

PART III *How can I prevent hazardous situations from occurring?*

7. HANDLING and STORAGE

WORK AND HYGIENE PRACTICES: As with all chemicals, avoid getting this material ON YOU or IN YOU. Wash thoroughly after handling this material. Do not eat, drink, smoke, or apply cosmetics while handling this material. Avoid breathing vapors or mists generated by this material. Use in a well-ventilated location. Remove contaminated clothing immediately.

STORAGE AND HANDLING PRACTICES: All employees who handle this material should be trained to handle it safely. Keep container tightly closed when not in use. Store containers in a cool, dry location, away from direct sunlight, sources of intense heat, or where freezing is possible. Material should be stored in secondary containers or in a diked area as appropriate. Store containers away from incompatible chemicals (see Section 10, Stability and Reactivity). Inspect all coming containers before storage to ensure containers are properly labeled and not damaged. Empty containers may contain residual liquid or vapors; therefore, empty containers should be handled with care. Never perform any welding, cutting, soldering, drilling, or other hot work on an empty container or piping until all liquid, vapors, and residue have been cleared.

7. HANDLING and STORAGE (Continued)

PROTECTIVE PRACTICES DURING MAINTENANCE OF CONTAMINATED EQUIPMENT: Follow practices indicated in Section 6 (Accidental Release Measures). Make certain that application equipment is locked and tagged-out safely, if necessary. Collect all rinsates and dispose of according to applicable U.S. Federal, State, or local procedures and appropriate Canadian standards, as well as those of the European Union member states.

8. EXPOSURE CONTROLS - PERSONAL PROTECTION

VENTILATION AND ENGINEERING CONTROLS: Use with adequate ventilation to ensure exposure levels are maintained below the limits provided below. Use local exhaust ventilation. Normal office ventilation conforming to the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Standards is adequate under normal circumstances of use. Persons using this material should consult a qualified Ventilation Engineer and/or Industrial Hygienist if concerns about exposures arise. If necessary, refer to Australian National Code of Practice for the Control of Workplace Hazardous Substances [NOHSC: 2007 (1994)] for further information. As with all chemicals, ensure proper decontamination equipment (e.g., eyewash/safety shower stations) is available near areas where this material is used as necessary.

EXPOSURE LIMITS/GUIDELINES:

CHEMICAL NAME	CAS #	EXPOSURE LIMITS IN AIR							
		ACGIH-TLVs		OSHA-PELs		NIOSH-RELs		NIOSH	OTHER
		TWA mg/m^3	STEL mg/m^3	TWA mg/m^3	STEL mg/m^3	TWA mg/m^3	STEL mg/m^3	IDLH mg/m^3	mg/m^3
Butoxy Triglycol	143-22-6	NE	NE	NE	NE	NE	NE	NE	NE
Proprietary Aliphatic Amide		NE	NE	NE	NE	NE	NE	NE	AIHA WEEL: TWA = 10
Proprietary Aliphatic Triol		10 ppm	NE	15 (Total dust) 5 (Resp. frac.) 10 (Total)	NE	NE	NE	NE	NE
Proprietary Black Pigment		NE	NE	NE	NE	NE	NE	NE	NE
Proprietary Propanediol		NE	NE	NE	NE	NE	NE	NE	NE

NE = Not Established. See Section 16 for Definitions of Terms Used.

INTERNATIONAL OCCUPATIONAL EXPOSURE LIMITS: In addition to the exposure limit values cited above, other exposure limits have been established by various countries for the components this product, as provided below: Note: Refer current country limits for complete information.

ALIPHATIC TRIOL:
Australia: TWA = 10 mg/m^3, JAN 1993
Belgium: TWA = 10 mg/m^3, JAN 1993
Finland: TWA = 20 mg/m^3, JAN 1999
France: VME = 10 mg/m^3, JAN 1999
The Netherlands: MAC-TGG = 10 mg/m^3, JAN 1999

ALIPHATIC TRIOL (continued):
United Kingdom: TWA = 10 mg/m^3, mist, SEP 2000
In Argentina, Bulgaria, Colombia, Jordan, Korea, New Zealand, Singapore, Vietnam check ACGIH TLV

PROPRIETARY PROPANEDIOL:
United Kingdom: TWA = 10 mg/m^3 (particulate), 2005
United Kingdom: TWA = 150 ppm (474 mg/m^3) (total vapor), 2005

RESPIRATORY PROTECTION: None needed under normal circumstances of use. If necessary, use only respiratory protection authorized in the U.S. Federal OSHA Respiratory Protection Standard (29 CFR 1910.134) and equivalent U.S. State standards, Canadian CSA Standard Z94.4-02, the European Standard EN 529:2005 and Respiratory Protection Standards of EU member states, or the Australian Standard 1716-Respiratory Protective Devices and Australian Standard 1715-Selection, Use, and Maintenance of Respiratory Protective Devices. Oxygen levels below 19.5% are considered IDLH by OSHA. In such atmospheres, use of a full-facepiece pressure/demand SCBA or a full facepiece, supplied air respirator with auxiliary self-contained air supply is required under U.S. Federal OSHA's Respiratory Protection Standard (1910.134-1998) or the regulations of various U.S. States, Canada, Australia, Japan, or EU Member States.

HAND PROTECTION: Wear butyl rubber gloves for routine use to prevent staining. Check gloves for leaks. If necessary, refer to U.S. OSHA 29 CFR 1910.138, the European Standard CEN/TR 15419:2006, the Australian Standard 2161-Industrial Safety Gloves and Mittens and appropriate Standards Canada for further information.

EYE PROTECTION: None needed under normal circumstances of use. Splash goggles or safety glasses should be worn during operations in which sprays of liquid may occur. If necessary, refer to U.S. OSHA 29 CFR 1910.133, the Canadian CSA Standard Z94.3-02. *Industrial Eye and Face Protectors*. the European Standard CR 13464:1999, or the Australian Standard 1337-Eye Protection for Industrial Applications and Australian Standard 1336-Recommended Practices for Eye Protection in the Industrial Environment for further information.

BODY PROTECTION: None needed under normal circumstances of use. Use body protection appropriate for task (e.g., rubber apron when cleaning equipment; Tyvek suit and rubber boots during non-incidental spill response). If necessary, refer to the European Standard CEN/TR 15419:2006 or Australian Standard 3765-Clothing for Protection Against Hazardous Chemicals for further information. If a hazard of injury to the feet exists due to falling objects, rolling objects, where objects may pierce the soles of the feet or where employee's feet may be exposed to electrical hazards, use foot protection, as described in U.S. OSHA 29 CFR 1910.136 and the Canadian CSA Standard Z195-02, *Protective Footwear*.

9. PHYSICAL and CHEMICAL PROPERTIES

VAPOR DENSITY (air = 1): Not established.
SPECIFIC GRAVITY (water = 1): Not established.
)LUBILITY IN WATER: Soluble
VAPOR PRESSURE: Not established.
ODOR THRESHOLD: Not established.
EVAPORATION RATE (*n*-BuAc = 1): Not established.
MELTING/FREEZING POINT: Not established.
BOILING POINT: Not established.
pH: Not applicable.
COEFFICIENT OF OIL/WATER DISTRIBUTION (PARTITION COEFFICIENT): Not established.
APPEARANCE, ODOR AND COLOR: This product is a black, liquid with a mild solvent odor.
HOW TO DETECT THIS SUBSTANCE (warning properties): The odor and color of this product may be distinguishing characteristics.

10. STABILITY and REACTIVITY

STABILITY: Stable under conditions of normal temperature and pressure. May form peroxides.
DECOMPOSITION PRODUCTS: If exposed to extremely high temperatures, this product can decompose to generate carbon oxides and nitrogen oxides.
MATERIALS WITH WHICH SUBSTANCE IS INCOMPATIBLE: Strong oxidizers and water-reactive materials.
HAZARDOUS POLYMERIZATION: Will not occur.
CONDITIONS TO AVOID: Exposure to or contact with extreme temperatures, incompatible chemicals.

PART IV *Is there any other useful information about this material?*

11. TOXICOLOGICAL INFORMATION

TOXICITY DATA: Specific toxicology data currently available for components of this product listed in Section 2 (Composition and Information on Ingredients) by CAS # are as follows.

BUTOXY TRIGLYCOL:
Open Irritation Test (skin, rabbit) = 10 mg/24 hours; Mild
Standard Draize Test (skin, rabbit) = 500 mg/24 hours; Mild
Standard Draize Test (eye, rabbit) = 50 mg; Severe
Standard Draize Test (eye, rabbit) = 20 mg/24 hours; Moderate
₀ (oral, rat) = 5300 mg/kg; Peripheral Nerve and Sensation: flaccid paralysis without anesthesia (usually neuromuscular blockage); Behavioral: altered sleep time (including change in righting reflex)
LD_{50} (skin, rabbit) = 3540 µL/kg; Skin and Appendages: primary irritation (after topical exposure)

ALIPHATIC TRIOL:
Skin Irritancy (rabbit) = 500 mg/24 hours; mild
Eye Irritancy (rabbit) = 126 mg; mild
Eye Irritancy (rabbit) = 500 mg/24 hours; mild
LD_{50} (oral, rat) = 12600 mg/kg; general anesthetic, muscle weakness, Liver: other changes
LC_{50} (inhalation, rat) > 570 mg/m^3/1 hour
LD_{50} (intraperitoneal, rat) = 4420 mg/kg; toxic psychosis; Cardiac; other changes; Kidney, Urethra, Bladder: other changes
LD_{50} (subcutaneous, rat) = 100 mg/kg
LD_{50} (intravenous, rat) = 5566 mg/kg
LD_{50} (oral, mouse) = 4090 mg/kg
LD_{50} (intraperitoneal, mouse) = 8700 mg/kg
LD_{50} (subcutaneous, mouse) = 91 mg/kg
LD_{50} (intravenous, mouse) = 4250 mg/kg
LD_{50} (oral, rabbit) = 27 g/kg
LD_{50} (skin, rabbit) > 10 g/kg
LD_{50} (intravenous, rabbit) = 53 g/kg
LD_{50} (oral, guinea pig) = 7750 mg/kg
TDLo (oral, rat) = 16800 mg/kg/28 days/continuous; Endocrine: changes in adrenal weight
TDLo (oral, rat) = 96 g/kg/30 days/intermittent; Blood: changes in leukocyte (WBC) count, changes in serum composition (e.g. TP, bilirubin, cholesterol); Biochemical: Enzyme inhibition, induction, or change in blood or tissue levels: true cholinesterase
TDLo (oral, rat) = 100 mg/kg/male 1 day pre-mating; Reproductive: Fertility: post-implantation mortality
₂Lo (intratesticular, rat) = 280 mg/kg/male 2 days pre-mating; Reproductive: Paternal Effects: spermatogenesis, testes, epididymis, sperm duct

ALIPHATIC TRIOL (continued):
TDLo (intratesticular, rat) = 1600 mg/kg/male 1 day pre-mating; Reproductive: Fertility: male fertility index
TDLo (intratesticular, rat) = 862 mg/kg/male 1 day pre-mating; Reproductive: Paternal Effects: spermatogenesis
TDLo (intratesticular, monkey) = 119 mg/kg/male 1 day pre-mating; Reproductive: Paternal Effects: spermatogenesis, testes, epididymis, sperm duct
TDLo (oral, mouse) = 560 g/kg/8 weeks/continuous; Lungs, Thorax, or Respiration: structural or functional change in trachea or bronchi
DNA Inhibition (human, lymphocyte) = 200 mmol/L
Cytogenetic Analysis (oral, rat) = 1 g/kg

PROPRIETARY PROPANEDIOL:
Standard Draize Test (Skin-Human) 10%/48 hours
Standard Draize Test (Skin-Human) 100%/48 hours: Moderate
Standard Draize Test (Skin-Human) 100%/7 days: Moderate
LD_{50} (Oral-Mouse) 4500 mg/kg
LD_{50} (Intraperitoneal-Mouse) 4780 mg/kg
LD_{50} (Unreported-Mouse) 10,930 mg/kg
LDLo (Oral-Rat) 10 gm/kg: Behavioral: somnolence (general depressed activity)
LDLo (Oral-Cat) 3 gm/kg: Behavioral: somnolence (general depressed activity)
LDLo (Intramuscular-Rat) 6 gm/kg: Behavioral: somnolence (general depressed activity)
LDLo (Intravenous-Rabbit) 3 gm/kg: Behavioral: somnolence (general depressed activity)
DNA (Oral-Rat) 2100 mg/kg/10 weeks-continuous

ALIPHATIC AMIDE:
Standard Draize Test (skin, human) = 22 mg/3 days-intermittent: Mild
TDLo (intraplacental, woman) = 1600 mg/kg: female 16 week(s) after conception: Reproductive: Fertility: abortion
TDLo (intraplacental, human) = 1400 mg/kg: female 16 week(s) after conception: Reproductive: Fertility: abortion
LD_{50} (oral, rat) = 8471 mg/kg
LD_{50} (intraperitoneal, rat) > 5 g/kg
LD_{50} (subcutaneous, rat) = 8200 mg/kg: Behavioral: altered sleep time (including change in righting reflex), changes in motor activity (specific assay); Behavioral: antipsychotic
LD_{50} (intravenous, rat) = 5300 mg/kg: Behavioral: altered sleep time (including change in righting reflex), changes in motor activity (specific assay), antipsychotic

ALIPHATIC AMIDE (continued):
LD_{50} (intratracheal, rat) = 567 mg/kg: Behavioral: convulsions or effect on seizure threshold; Lungs, Thorax, or Respiration: dyspnea; Blood: methemoglobinemia-carboxyhemoglobin
LD_{50} (oral, mouse) = 11 g/kg
LD_{50} (subcutaneous, mouse) = 9200 mg/kg: Behavioral: altered sleep time (including change in righting reflex), changes in motor activity (specific assay), antipsychotic
LD_{50} (intravenous, mouse) = 4600 mg/kg: Behavioral: altered sleep time (including change in righting reflex), changes in motor activity (specific assay), antipsychotic
LDLo (intraperitoneal, mouse) = 6608 mg/kg: Behavioral: convulsions or effect on seizure threshold, coma
LDLo (subcutaneous, dog) = 3 g/kg
LDLo (intravenous, dog) = 3 g/kg
LDLo (intravenous, rabbit) = 4800 mg/kg
LDLo (oral, rabbit) = 10 g/kg: Brain and Coverings: other degenerative changes; Lungs, Thorax, or Respiration: structural or functional change in trachea or bronchi; Blood: hemorrhage
LDLo (subcutaneous, rabbit) = 3 g/kg
LDLo (oral, domestic mammal) = 511 mg/kg: Behavioral: tetany; Lungs, Thorax, or Respiration: dyspnea; Gastrointestinal: changes in structure or function of salivary glands
LDLo (subcutaneous, pigeon) = 14,800 mg/kg
LDLo (subcutaneous, frog) = 600 mg/kg
TCLo (inhalation, rat) = 288 mg/m^3/17 weeks-intermittent: Kidney, Ureter, Bladder other changes in urine composition; Blood: other changes; Nutritional and Gross Metabolic: changes in chlorine
TDLo (oral, rat) = 3024 mg/kg/4 weeks-continuous: Liver: changes in liver weight; Endocrine: changes in thymus weight; Related to Chronic Data: changes in testicular weight
TDLo (skin, rat) = 37,800 mg/kg/25 weeks-continuous: Brain and Coverings: changes in brain weight; Related to Chronic Data: changes in prostate weight
TDLo (oral, rat) = 821 g/kg/1 year-continuous: Tumorigenic: neoplastic by RTECS criteria; Blood: tumors; Blood: lymphoma, including Hodgkin's disease
TDLo (oral, mouse) = 394 g/kg/1 year-continuous: Tumorigenic: carcinogenic by RTECS criteria; Blood: tumors; Blood: lymphoma, including Hodgkin's disease

11. TOXICOLOGICAL INFORMATION (Continued)

TOXICITY DATA (continued):

ALIPHATIC AMIDE (continued):

TDLo (oral, cattle) = 200 mg(N)/kg: Behavioral: tremor, muscle weakness; Gastrointestinal: alteration in gastric secretion

TDLo (intrauterine, monkey) = 6 g/kg: female 18 week(s) after conception: Reproductive: Fertility: abortion

ALIPHATIC AMIDE (continued):

DNA Inhibition (lymphocyte, human) = 600 mmol/L

Cytogenetic Analysis (lymphocyte, human) = 50 mmol/L

Cytogenetic Analysis (oral, mouse) = 100 g/kg/5 days-continuous

ALIPHATIC AMIDE (continued):

Cytogenetic Analysis (fibroblast, hamster) = 16 g/L/24 hours

Cytogenetic Analysis (lung, hamster) = 13 g/L

DNA Damage (lymphocyte, mouse) = 628 mmol/L

DNA Damage (fibroblast, hamster) = 8 mol/L

Mutation in Mammalian Somatic Cells (lymphocyte, mouse) = 265 mmol/L

SUSPECTED CANCER AGENT: The components of this product listed are not found on the following lists: FEDERAL OSHA Z LIST, NTP, IARC, and CAL/OSHA and therefore are neither considered to be nor suspected to be cancer-causing agents by these agencies.

IRRITANCY OF PRODUCT: Acute exposure to this material via skin contact, eye contact, and inhalation may irritate contaminated tissue.

SENSITIZATION TO THE PRODUCT: The components of this product are not known to be sensitizers with prolonged or repeated use.

REPRODUCTIVE TOXICITY INFORMATION: Listed below is information concerning the effects of components of this product on the human reproductive system.

Mutagenicity: The components of this product are not reported to produce mutagenic effects in humans.

Embryotoxicity: The components of this product are not reported to produce embryotoxic effects in humans.

Teratogenicity: The components of this product are not reported to cause teratogenic effects in humans.

Reproductive Toxicity: The components of this product are not reported to cause reproductive effects in humans.

A mutagen is a chemical that causes permanent changes to genetic material (DNA) such that the changes will propagate through generational lines. An embryotoxin is a chemical that causes damage to a developing embryo (i.e. within the first eight weeks of pregnancy in humans), but the damage does not propagate across generational lines. A teratogen is a chemical that causes damage to a developing fetus, but the damage does not propagate across generational lines. A reproductive toxin is any substance that interferes in any way with the reproductive process.

BIOLOGICAL EXPOSURE INDICES: Currently, there are no Biological Exposure Indices (BEIs) established for the components of this product.

12. ECOLOGICAL INFORMATION

ALL WORK PRACTICES MUST BE AIMED AT ELIMINATING ENVIRONMENTAL CONTAMINATION.

ENVIRONMENTAL STABILITY: This product is relatively stable under ambient environmental conditions. Additional environmental data for the main components of this product are available as follows:

BUTOXY TRIGLYCOL:

Terrestrial Fate: Based on a recommended classification scheme, an estimated Koc value of 10, determined from a structure estimation method, indicates that Triethylene Glycol Monobutyl Ether may have very high mobility in soil. Volatilization of Triethylene Glycol Monobutyl Ether is not expected to be important from moist soil surfaces given an estimated Henry's Law constant of 9.5X10-14 atm-cu m/mole, or from dry soil surfaces, based on an experimental vapor pressure of 2.5X10-3 mm Hg. According to a biodegradation study, Triethylene Glycol Monobutyl Ether should biodegrade slowly in soil.

Aquatic Fate: Based on a recommended classification scheme, an estimated Koc value of 10, determined from a structure estimation method, indicates that Triethylene Glycol Monobutyl Ether would not adsorb to suspended solids and sediment in the water. Triethylene Glycol Monobutyl Ether will be essentially non-volatile from water surfaces based on an estimated Henry's Law constant of 9.5X10-14 atm-cu m/mole, developed using a fragment constant estimation method(3). An estimated BCF value of 0.6, from an estimated log Kow, suggests that Triethylene Glycol Monobutyl Ether will not bioconcentrate in aquatic organisms, according to a recommended classification scheme. According to a biodegradation study, Triethylene Glycol Monobutyl Ether should biodegrade slowly in water.

Atmospheric Fate: According to a model of gas/particle partitioning of semi-volatile organic compounds in the atmosphere Triethylene Glycol Monobutyl Ether, which has an experimental vapor pressure of 2.5X10-3 mm Hg at 25°C, will exist as a vapor in the ambient atmosphere. Vapor-phase Triethylene Glycol Monobutyl Ether is degraded in the atmosphere by reaction with photochemically produced hydroxyl radicals; the half-life for this reaction in air is estimated to be about 7.5 hours.

Bioconcentration: An estimated BCF value of 0.6 was calculated for Triethylene Glycol Monobutyl Ether, using an estimated log Kow of 0.02 and a recommended regression-derived equation. According to a recommended classification scheme, this BCF value suggests that bioconcentration in aquatic organisms will not be an important fate process.

ALIPHATIC TRIOL:

Water Solubility = Miscible. Log K_{ow} = -1.76.

5-Day Biological Oxygen Demand = 0.54 p/p; 10 day BOD = 0.98 p/p; 20 Day BOD = 1.0 p/p:

Terrestrial Fate: If released to soil, this compound is expected to undergo rapid biodegradation under aerobic conditions. Biodegradation is also expected under anaerobic condition. Based on its Log Kow of -1.76 and its water solubility, the soil absorption coefficients for this compound can be estimated at 3 and 2, respectively, using regression-derived equations. These values indicated that this material will be highly mobile in soil. This compound is not expected to significantly volatilize from most or dry soil to the atmosphere.

Aquatic Fate: If released to an aquatic environment, this material is expected to rapidly degrade under aerobic conditions. Degradation is also likely in seawater and under anaerobic conditions. Based on water solubility and its Log Kow, the bioconcentration factors for this compound can be estimated at 3 and 0.2, respectively. These values indicate that bioconcentration is not significant in aquatic organisms.

Atmospheric Fate: If released to the atmosphere, this material may undergo a gas-phase oxidization with photochemically produced hydroxyl radicals. An estimated reaction rate indicates that the atmospheric half-life of this compound in the atmosphere to be 33 hours. The water solubility of this material indicates that is may also undergo atmospheric removal by wet deposition processes.

ALIPHATIC AMIDE:

Terrestrial Fate: Based on a classification scheme, a Koc value of 8 indicates that this material is expected to have very high mobility in soil. Volatilization of this compound from moist soil surfaces is not expected to be an important fate process given an estimated Henry's Law constant of 1.74X10-12 atm-cu m/mole determined from its vapor pressure, 1.20X10-5 mm Hg, and water solubility, 5.45x10+5 mg/L. This material is not expected to volatilize from dry soil surfaces based upon its vapor pressure. Various field and laboratory studies have demonstrated that this material degrades rapidly in most soils. This compound is rapidly hydrolyzed to ammonium ions through soil activity which produces volatile gases, i.e., ammonia and carbon dioxide. In a variety of soils, the hydrolysis may near completion within 24 hours. However, the rate of hydrolysis can be much slower depending upon the soil type, moisture content, and formulation. For example, increasing the pellet size of amide-based fertilizers can decrease the rate of this material decomposition from days to weeks. In a study examining the fate of soil-applied material, a major part (e.g., 22-49%) of the applied material was lost in gaseous form (e.g., ammonia or N2O). Although soil adsorption studies have demonstrated that this compound adsorbs very weakly to soil; only a minor part was leached out of soil (< 1%) in this study. Roughly one third (e.g., 26-43%), however, was incorporated into soil organic matter.

12. ECOLOGICAL INFORMATION (Continued)

ENVIRONMENTAL STABILITY (continued):

ALIPHATIC AMIDE (continued):

Aquatic Fate: Based on a classification scheme, a Koc value of 8 indicates that this material is not expected to adsorb to suspended solids and sediment. Volatilization from water surfaces is not expected based upon an estimated Henry's Law constant of 1.74X10-12 atm-cu m/mole determined from its vapor pressure, 1.20 X 10-5 mm Hg, and water solubility, 5.45X10+5 mg/L. According to a classification scheme, BCF values of 1 and < 10 suggest the potential for bioconcentration in aquatic organisms is low. This compound is rapidly hydrolyzed to ammonia and carbon dioxide in environmental systems by the extra-cellular enzyme, which originates from microorganisms and plant roots. The degradation of this compound was examined in a river die-away study using various river waters and test conditions. At 20°C, degradation of this compound was complete within 6-14 days of incubation, while at lower temperatures (e.g., 4-12°C) little or no degradation occurred in 10-14 days. Abiotic hydrolysis of this compound occurs very slowly in relation to biotic hydrolysis.

Atmospheric Fate: According to a model of gas/particle partitioning of semi-volatile organic compounds in the atmosphere), this material, which has a vapor pressure of 1.2X10-5 mm Hg at 25°C, will exist in both the vapor and particulate phases in the ambient atmosphere. Vapor-phase material is degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be 9.6 days, calculated from its rate constant of 4.00 X 10-11 cu cm/molecule-sec at 25°C. Particulate-phase material may be removed from the air by wet and dry deposition.

Bioconcentration: In a 6 to 72 hours bioaccumulation study using carp (*Cyprinus carpio*), the concentration of this material was found to be equally distributed between tissue and water during all time periods; thus, the BCF would be 1 for this species. In 3-day static-system tests using golden ide fish (Leuciscus idus melanotus), the BCF of this material was < 10. According to a classification scheme, these BCF values suggest the potential for bioconcentration in aquatic organisms is low.

EFFECT OF MATERIAL ON PLANTS or ANIMALS: This product may be harmful to plant or animal life, especially if large volumes of this product are released. Plants may be discolored and damaged (depending on the severity of the contamination).

EFFECT OF CHEMICAL ON AQUATIC LIFE: This product may be harmful to aquatic plant or animal life, especially if large volumes of this product are released into a body of water. Additional aquatic toxicity data for components of this product are available as follows:

ALIPHATIC TRIOL:

EC_0 (*Pseudomonas putida* bacteria) 16 hours = >10,000 mg/L
EC_0 (*Microcystis aeruginosa* algae) 8 days = 2,900 mg/L
EC_0 (*Scenedesmus quadricauda* green algae) 7 days = > 10,000 mg/L
EC_0 (*Entosiphon sulcatum* protozoa) 72 hours = 3,200 mg/L
EC_0 (*Uronema parduczi* Chatton-Lwoff protozoa) = > 10,000 mg/L
LC_{50} (goldfish) 24 hours = > 5,000 mg/

ALIPHATIC AMIDE:

Toxicity Threshold (*Scenedesmus quadricauda* green algae) > 10,000 mg/L, toxic effect: multiplication inhibition of cell. /Time not specified
Toxicity Threshold (*Entosiphon sulcatum* protozoa) > 29 mg/L, toxic effect: inhibition of cell multiplication./Time not specified
Toxicity Threshold (Pseudomonas putida) > 10,000 mg/L toxic effect: inhibition of cell multiplication. /Time not specified

13. DISPOSAL CONSIDERATIONS

PREPARING WASTES FOR DISPOSAL: Waste disposal must be in accordance with appropriate U.S. Federal, State, and local regulations or with regulations of Canada, Australia, or EU Member States. This material, if unaltered by use, may be disposed of by treatment at a permitted facility or as advised by your local hazardous waste regulatory authority.

U.S. EPA WASTE NUMBER: Not applicable to wastes consisting only of this product.

EUROPEAN EWC WASTE CODES: 08: Wastes from the Manufacture, Formulation, Supply and Use (mfsu) of Coatings (Paints, Varnishes and Vitreous Enamels), Adhesives, Sealants and Printing Inks 04 99: Wastes not otherwise specified.

14. TRANSPORTATION INFORMATION

THIS PRODUCT IS NOT HAZARDOUS AS DEFINED BY 49 CFR 172.101 BY THE U.S. DEPARTMENT OF TRANSPORTATION.

PROPER SHIPPING NAME:	Not Regulated
HAZARD CLASS NUMBER and DESCRIPTION:	Not Applicable
UN IDENTIFICATION NUMBER:	Not Applicable
PACKING GROUP:	Not Applicable
DOT LABEL(S) REQUIRED:	Not Applicable

EMERGENCY RESPONSE GUIDEBOOK NUMBER, 2004: Not Applicable

MARINE POLLUTANT: The components of this product listed in Section 2 (Composition and Information on Ingredients) by CAS # are not designated by the DOT to be Marine Pollutants (per Appendix B to 49 CFR 172.101).

TRANSPORT CANADA, TRANSPORTATION OF DANGEROUS GOODS REGULATIONS: This product is NOT classified as dangerous goods, per regulations of Transport Canada.

INTERNATIONAL AIR TRANSPORT ASSOCIATION SHIPPING INFORMATION (IATA): This product is NOT classified as dangerous goods.

INTERNATIONAL MARITIME ORGANIZATION SHIPPING INFORMATION (IMO): This product is NOT classified as dangerous goods.

EUROPEAN AGREEMENT CONCERNING THE INTERNATIONAL CARRIAGE OF DANGEROUS GOODS BY ROAD (ADR): This product is NOT classified by the United Nations Economic Commission for Europe to be dangerous goods.

AUSTRALIAN FEDERAL OFFICE OF ROAD SAFETY CODE FOR THE TRANSPORTATION OF DANGEROUS GOODS BY ROAD OR RAIL: This product is NOT classified as dangerous goods, per regulations of the Australian Federal Office of Road Safety.

15. REGULATORY INFORMATION

ADDITIONAL UNITED STATES REGULATIONS:

U.S. SARA REPORTING REQUIREMENTS: Some components of this product are subject to the reporting requirements of sections 302, 304 and 313 of Title III of the Superfund Amendments and Reauthorization Act, as follows:

CHEMICAL NAME	SARA 302 (40 CFR 355, Appendix A)	SARA 304 (40 CFR Table 302.4)	SARA 313 (40 CFR 372.65)
Butoxy Triglycol (in generic Glycol Ether category)	No	No	N230

U.S. SARA THRESHOLD PLANNING QUANTITY: There are no specific Threshold Planning Quantities for this material. The default Federal MSDS submission and inventory requirement filing threshold of 10,000 lb (4,540 kg) may apply, per 40 CFR 370.20.

U.S. CERCLA REPORTABLE QUANTITY (RQ): Butoxy Triglycol = Under the generic Glycol Ether category, this compound does not have a RQ assigned, but is considered a CERCLA Hazardous Waste.

U.S. TSCA INVENTORY STATUS: The components of this product are listed on the TSCA Inventory.

U.S. HAZARDOUS AIR POLLUTANT (HAPs): The components of this product are not listed by the EPA under section 112(b) of the Clean Air Act as a 'HAP'.

OTHER U.S. FEDERAL REGULATIONS: Not applicable.

CALIFORNIA SAFE DRINKING WATER AND TOXIC ENFORCEMENT ACT (PROPOSITION 65): The components of this product are not on the Proposition 65 Lists.

ANSI LABELING (Z129.1): **CAUTION!** MAY CAUSE EYE AND RESPIRATORY TRACT IRRITATION. PROLONGED OR REPEATED CONTACT MAY DRY SKIN AND CAUSE IRRITATION. MAY DISCOLOR CONTAMINATED SKIN, EYES, HAIR, AND CLOTHES. FOR INDUSTRIAL USE ONLY. KEEP OUT OF REACH OF CHILDREN. Use with adequate ventilation. Avoid contact with skin, eyes, and clothing. Avoid breathing vapors, mists, or sprays. Wash thoroughly after handling. Wear appropriate hand and eye protection. **FIRST-AID:** In case of contact, immediately flush skin or eyes with plenty of water. Remove contaminated clothing and shoes. If inhaled, remove to fresh air. If swallowed, do not induce vomiting. Get medical attention if irritation develops or persists or if any other adverse effect occurs. **IN CASE OF FIRE:** Use water fog, dry chemical, or CO_2, or alcohol foam. **IN CASE OF SPILL:** Absorb spill with inert materials (e.g., polypads, dry sand). Rinse area with soapy water. Consult Material Safety Data Sheet for additional information.

ADDITIONAL CANADIAN REGULATIONS:

CANADIAN DSL/NDSL INVENTORY STATUS: The components of this product are listed on the DSL Inventory.

CANADIAN ENVIRONMENTAL PROTECTION ACT (CEPA) PRIORITY SUBSTANCES LISTS: The components of this product listed are not on the CEPA Priority Substances Lists.

CANADIAN WHMIS CLASSIFICATION and SYMBOLS: Not applicable.

EUROPEAN UNION INFORMATION:

EU LABELING/CLASSIFICATION: This product does not meet the definition of any hazard class, as defined by the European Union Council Directives 67/548/EEC and 2001/59/EC. (See Section 15 for details on classification)

EU CLASSIFICATION: Not applicable.
EU RISK PHRASES: Not applicable.
EU SAFETY PHRASES: Not applicable.

EUROPEAN UNION ANNEX II HAZARD SYMBOL: Not applicable.

AUSTRALIAN INFORMATION FOR PRODUCT:

AUSTRALIAN INVENTORY OF CHEMICAL SUBSTANCES (AICS) STATUS: The components of this product are listed on the AICS.

HAZARDOUS SUBSTANCES INFORMATION SYSTEM (HSIS): No component of this product is listed in the HSIS.

STANDARD FOR THE UNIFORM SCHEDULING OF DRUGS AND POISONS: Not applicable.

LABELING AND CLASSIFICATION: This product does not meet the definition of any hazard class, based a review of the regulation [NOHSC: 10005 (1994)]:

CLASSIFICATION: Not applicable.
RISK PHRASES: Not applicable.
SAFETY PHRASES: Not applicable.
HAZARD SYMBOL: Not applicable.

JAPANESE INFORMATION FOR PRODUCT:

JAPANESE MINISTRY OF ECONOMY, TRADE, AND INDUSTRY (METI) STATUS: The components of this product are not listed as Class I Specified Chemical Substances, Class II Specified Chemical Substances, or Designated Chemical Substances by the Japanese METI.

16. OTHER INFORMATION

PREPARED BY: CHEMICAL SAFETY ASSOCIATES, Inc.
PO Box 3519, La Mesa, CA 91944-3519
800/441-3365

DATE OF PRINTING: January 28, 2009

The data in this Material Safety Data Sheet is true and accurate to the best of Prism Inks, Inc. knowledge. However, since data, safety standards, and government regulations are subject to change conditions of handling, use, or misuse are beyond Prism Inks, Inc. control, Prism Inks, Inc. MAKES NO WARRANTY, EITHER EXPRESSED OR IMPLIED, WITH RESPECT TO THE COMPLETENESS OR CONTINUING ACCURACY OF THE INFORMATION CONTAINED HEREIN AND DISCLAIMS ALL LIABILITY FOR RELIANCE THEREON. The user is required to comply with all laws and regulations relating to the purchase, use, storage, and disposal of the product. User must be familiar with and follow generally accepted safe handling procedures of chemicals, and is solely responsible for any effects caused by its misuse or mixing of this chemical with any other substance.

DEFINITIONS OF TERMS

A large number of abbreviations and acronyms appear on a MSDS. Some of these, which are commonly used, include the following:

CAS #: This is the Chemical Abstract Service Number that uniquely identifies each constituent.

EXPOSURE LIMITS IN AIR:

CEILING LEVEL: The concentration that shall not be exceeded during any part of the working exposure.

DFG MAK Germ Cell Mutagen Categories: 1: Germ cell mutagens which have been shown to increase the mutant frequency in the progeny of exposed humans. **2:** Germ cell mutagens which have been shown to increase the mutant frequency in the progeny of exposed mammals. **3A:** Substances which have been shown to induce genetic damage in germ cells of human of animals, or which produce mutagenic effects in somatic cells of mammals *in vivo* and have been shown to reach the germ cells in an active form. **3B:** Substances which are suspected of being germ cell mutagens because of their genotoxic effects in mammalian somatic cell *in vivo*; in exceptional cases, substances for which there are no *in vivo* data, but which are clearly mutagenic *in vitro* and structurally related to known in vivo mutagens. **4:** Not applicable (Category 4 carcinogenic substances are those with non-genotoxic mechanisms of action. By definition, germ cell mutagens are genotoxic. Therefore, a Category 4 for germ cell mutagens cannot apply. At some time in the future, it is conceivable that a Category 4 could be established for genotoxic substances with primary targets other than DNA [e.g. purely aneugenic substances] if research results make this seem sensible.) **5:** Germ cell mutagens, the potency of which is considered to be so low that, provided the MAK value is observed, their contribution to genetic risk for humans is expected not to be significant.

DFG MAK Pregnancy Risk Group Classification: Group A: A risk of damage to the developing embryo or fetus has been unequivocally demonstrated. Exposure of pregnant women can cause damage of the developing organism, even when MAK and BAT (Biological Tolerance Value for Working Materials) values are observed. **Group B:** Currently available information indicates a risk of damage to the developing embryo or fetus must be considered to be probable. Damage to the developing organism cannot be excluded when pregnant women are exposed, even when MAK and BAT values are observed. **Group C:** There is no reason to fear a risk of damage to the developing embryo or fetus when MAK and BAT values are observed. **Group D:** Classification in one of the groups A-C is not yet possible because, although the data available may indicate a trend, they are not sufficient for final evaluation.

IDLH-Immediately Dangerous to Life and Health: This level represents a concentration from which one can escape within 30-minutes without suffering escape-preventing or permanent injury.

LOQ: Limit of Quantitation.

MAK: Federal Republic of Germany Maximum Concentration Values in the workplace.

NE: Not Established. When no exposure guidelines are established, an entry of NE is made for reference.

NIC: Notice of Intended Change.

NIOSH CEILING: The exposure that shall not be exceeded during any part of the workday. If instantaneous monitoring is not feasible, the ceiling shall be assumed as a 15-minute TWA exposure (unless otherwise specified) that shall not be exceeded at any time during a workday.

NIOSH RELs: NIOSH's Recommended Exposure Limits.

PEL-Permissible Exposure Limit: OSHA's Permissible Exposure Limits. This exposure value means exactly the same as a TLV, except that it is enforceable by OSHA. The OSHA Permissible Exposure Limits are based in the 1989 PELs and the June, 1993 Air Contaminants Rule (Federal Register: 58: 35338-35351 and 58: 40191). Both the current PELs and the vacated PELs are indicated. The phrase, "Vacated 1989 PEL," is placed next to the PEL that was vacated by Court Order.

SKIN: Used when a there is a danger of cutaneous absorption.

STEL-Short Term Exposure Limit: Short Term Exposure Limit, usually a 15-minute time-weighted average (TWA) exposure that should not be exceeded at any time during a workday, even if the 8-hr TWA is within the TLV-TWA, PEL-TWA or REL-TWA.

EXPOSURE LIMITS IN AIR (continued):

TLV-Threshold Limit Value: An airborne concentration of a substance that represents conditions under which it is generally believed that nearly all workers may be repeatedly exposed without adverse effect. The duration must be considered, including the 8-hour.

TWA-Time Weighted Average: Time Weighted Average exposure concentration for a conventional 8-hr (TLV, PEL) or up to a 10-hr (REL) workday and a 40-hr workweek.

HAZARDOUS MATERIALS IDENTIFICATION SYSTEM

HAZARD RATINGS: This rating system was developed by the National Paint and Coating Association and has been adopted by industry to identify the degree of chemical hazards.

HEALTH HAZARD:

0 (Minimal Hazard: No significant health risk, irritation of skin or eyes not anticipated. *Skin Irritation*: Essentially non-irritating. PII or Draize = "0". *Eye Irritation*: Essentially non-irritating, or minimal effects which clear in < 24 hours [e.g. mechanical irritation]. Draize = "0". *Oral Toxicity LD_{50} Rat*: < 5000 mg/kg. *Dermal Toxicity LD_{50} Rat or Rabbit*: < 2000 mg/kg. *Inhalation Toxicity 4-hrs LC_{50} Rat*: < 20 mg/L.); **1** (Slight Hazard: Minor reversible injury may occur; slightly or mildly irritating. *Skin Irritation*: Slightly or mildly irritating. *Eye Irritation*: Slightly or mildly irritating. *Oral Toxicity LD_{50} Rat*: > 500-5000 mg/kg. *Dermal Toxicity LD_{50} Rat or Rabbit*: > 1000-2000 mg/kg. *Inhalation Toxicity LC_{50} 4-hrs Rat*: > 2-20 mg/L); **2** (Mild Hazard: Temporary or transitory injury may occur. *Skin Irritation*: Mildly irritating; primary irritant; sensitizer. PII or Draize > 0, < 5. *Eye Irritation*: Mildly to severely irritating and/or corrosive; reversible corneal opacity; corneal involvement or irritation clearing in 8-21 days. Draize > 0, ≤ 25. *Oral Toxicity LD_{50} Rat*: > 50-500 mg/kg. *Dermal Toxicity LD_{50} Rat or Rabbit*: > 200-1000 mg/kg. *Inhalation Toxicity LC_{50} 4-hrs Rat*: > 0.5-2 mg/L.);**3** (Serious Hazard: Major injury likely unless prompt action is taken and medical treatment is given; high level of toxicity; corrosive. *Skin Irritation*: Severely irritating and/or corrosive; may destroy dermal tissue, cause skin burns, dermal necrosis. PII or Draize > 5-8 with destruction of tissue. *Eye Irritation*: Corrosive, irreversible destruction of ocular tissue; corneal involvement or irritation persisting for more than 21 days. Draize > 80 with effects irreversible in 21 days. *Oral Toxicity LD_{50} Rat*: > 1-50 mg/kg. *Dermal Toxicity LD_{50} Rat or Rabbit*: > 20-200 mg/kg. *Inhalation Toxicity LC_{50} 4-hrs Rat*: > 0.05-0.5 mg/L.); **4** (Severe Hazard: Life-threatening; major or permanent damage may result from single or repeated exposure. *Skin Irritation*: Not appropriate. Do not rate as a "4", based on skin irritation alone. *Eye Irritation*: Not appropriate. Do not rate as a "4", based on eye irritation alone. *Oral Toxicity LD_{50} Rat*: ≤ 1 mg/kg. *Dermal Toxicity LD_{50} Rat or Rabbit*: ≤ 20 mg/kg. *Inhalation Toxicity LC_{50} 4-hrs Rat*: ≤ 0.05 mg/L).

FLAMMABILITY HAZARD:

0 (Minimal Hazard-Materials that will not burn in air when exposure to a temperature of 815.5°C [1500°F] for a period of 5 minutes.); **1** (Slight Hazard-Materials that must be pre-heated before ignition can occur. Material require considerable pre-heating, under all ambient temperature conditions before ignition and combustion can occur, Including: Materials that will burn in air when exposed to a temperature of 815.5°C (1500°F) for a period of 5 minutes or less; Liquids, solids and semisolids having a flash point at or above 93.3°C [200°F] (e.g. OSHA Class IIIB, or; Most ordinary combustible materials [e.g. wood, paper, etc.]; **2** (Mild Hazard-Materials that must be mildly heated or exposed to relatively high ambient temperatures before ignition can occur. Materials in this degree would not, under normal conditions, form hazardous atmospheres in air, but under high ambient temperatures or mild heating may release vapor in sufficient quantities to produce hazardous atmospheres in air, Including: Liquids having a flash-point at or above 37.8°C [100°F]; Solid materials in the form of course dusts that may burn rapidly but that generally do not form explosive atmospheres; Solid materials in a fibrous or shredded form that may burn rapidly and create flash fire hazards (e.g. cotton, sisal, hemp; Solids and semisolids that readily give off flammable vapors.); **3** (Serious Hazard- Liquids and solids that can be ignited under almost all ambient temperature conditions. Materials in this degree produce hazardous atmospheres with air under almost all ambient temperatures, or, unaffected by ambient temperature, are readily ignited under almost all conditions, including:

APPENDIX F
MSDS FOR INTRINSIQ COPPER INK

March 2010

MATERIAL SAFETY DATA SHEET

1. Identification of Substance and Company

Product Name: Nano-Copper based Printing Ink (Research Sample)
ID: Intrinsiq CI-002

Supplier: Intrinsiq Materials Ltd, Cody Technology Park, Ively Road, Farnborough, Hampshire GU14 0LX, UK
Tel: +44 (0) 1252 395515
Fax: +44 (0) 1252 397184
Emergency mobile: + 44 (0) 7872 692063 *(24hr)*

2. Composition and Details

Chemical Name(s): Nano Copper (incorporating proprietary organic coating) 10-15 Wt%
Ethane-1,2-diol up to 80%Wt. CAS No. **107-21-1**
n-Butanol up to 20% Wt. CAS No. **71-36-3**

3. Hazards

WARNING! HARMFUL OR FATAL IF SWALLOWED. HARMFUL IF INHALED OR ABSORBED THROUGH SKIN. MAY CAUSE ALLERGIC SKIN REACTION. MAY CAUSE IRRITATION TO SKIN, EYES, AND RESPIRATORY TRACT. AFFECTS CENTRAL NERVOUS SYSTEM.

Hazards: Flammable Liquid
Inhalation: Harmful if inhaled
Ingestion: The toxicological properties of this sample have not been fully investigated. Ethane-1,2-diol consumption in massive dosage parallels alcohol intoxication, progressing to CNS depression, vomiting, headache, rapid respiratory and heart rate, lowered blood pressure, stupor, collapse, and unconsciousness with convulsions. Death from respiratory arrest or cardiovascular collapse may follow.
Skin: Material may be skin absorbed
Eye: May cause eye irritation

Target Organs Liver, Cardiovascular system, Eyes, Kidney, Central nervous system

4. First Aid Measures

Skin contact: Remove contaminated clothing, flood skin with a large amount of water - if irritation persists, seek medical attention

Eye contact: Check for contact lenses, immediately flush eyes *(including under eyelids)* with large amounts of water for at least 15 minutes. - seek medical attention

Ingestion: **Seek immediate medical attention.**
Signs and Symptoms of Exposure (Ethane-1,2-diol ingestion)
When ingested early symptoms mimic alcohol inebriation and are followed

by nausea, vomiting, abdominal pain, weakness, muscle tenderness, respiratory failure, convulsions, cardiovascular collapse, pulmonary edema, hypocalcemic tetany, and severe metabolic acidosis. Without treatment, death may occur in 8 to 24 hours. Victims who survive the initial toxicity period usually develop renal failure along with brain and liver damage., Exposure to and/or consumption of alcohol may increase toxic effects

Inhalation: Remove victim to fresh air - if not breathing, give artificial respiration - if breathing difficult, give oxygen – seek medical attention

5. Fire Fighting Measures

Extinguishing media: DO NOT USE water, CO_2 or halogenated extinguishing agents - use dry chemical extinguishing agents *(e.g. sand or ground dolomite)*

Specific Hazards: Toxic gases and vapors may be released if involved in a fire

Special Protective Equipment In the event of a fire, wear full protective clothing and a suitable NIOSH/MSHA approved self-contained breathing apparatus with full face piece operated in the pressure demand or other positive pressure mode

6. Accidental Release Measures

Methods for Cleaning Up: Ventilate area of leak or spill. Remove all sources of ignition. Wear appropriate personal protective equipment as specified in Section 8. Isolate hazard area. Keep unnecessary and unprotected personnel from entering. Contain and recover liquid when possible. Use non-sparking tools and equipment. Collect liquid in an appropriate container or absorb with an inert material (e. g., vermiculite, dry sand, earth), and place in a chemical waste container

Environmental Protection: Do not release to drains or the environment.
Use authorised waste disposal service that complies with local and national regulations

7. Handling and Storage

Stability: Stable under ordinary conditions of use. Material is a research sample and has a nominal shelf-life of 3 months for use in printing applications

Handling: Use local exhaust ventilation over processing equipment to maintain concentration at or below the PEL, TLV

Storage: Store in a tightly closed container in a cool, dry, area. Only open in well ventilated area. Material is highly hygroscopic

8. Exposure controls/Personal Protection

Copper dust and mists:
OSHA Permissible Exposure Limit (PEL) 1 mg/m^3 (TWA)
ACGIH Threshold Limit Value (TLV) 1 mg/m^3 (TWA)
NIOSH Recommended Exposure Limit (REL) 1 mg/m^3 (TWA)

Copper Fume:
OSHA Permissible Exposure Limit (PEL) 0.1 mg/m^3
ACGIH Threshold Limit Value (TLV) 0.2 mg/m^3 (TWA)

Ethane-1,2-diol

TWA	STEL
20 ppm	40 ppm
52 mg/m^3	104 mg/m^3

n-butanol
STEL 50 ppm / 154 mg/m^3

Exposure controls exhaust:	Avoid inhaling vapour. Use local ventilation over processing equipment
Personal protection:	Observe good standard of industrial hygiene, wear a mask or dust respirator
Hand protection:	Wear protective gloves
Eye protection:	Wear safety spectacles or goggles
Skin and body protection:	Wear protective clothing
Respiratory:	Wear approved/certified respirator

9. Physical and Chemical Properties

Physical form:	Viscous Liquid
Colour:	Black
Melting point:	N/A
Boiling point:	
Flash point:	No data available
Auto ignition temperature:	No data available

Incompatibility (materials to avoid): Strong acids, strong oxidizers, halogens, acid chlorides, chlorates, bromates, iodates,

Hazardous decomposition products: Hazardous decomposition products may form under fire conditions.

10. Toxicological Information

Acute toxicity:	Toxicity as formulated – data not currently available. Ethane-1,2-diol component in isolation LD50 Oral - rat - 4,700 mg/kg LD50 Dermal - rabbit - 10,626 mg/kg
Skin contact:	Not known (treat as hazardous)
Eye contact:	Not known (treat as hazardous)
Sensitisation	No data available

Mutagenicity: Laboratory experiments have shown teratogenic effects (ethane-1,2-diol).

11. Ecological Information

Biodegradability Not known.

12. Disposal considerations

Disposal of product: Landfill or incineration at approved waste disposal sites in accordance with national and local regulations.

13. Transport Information

Hazard Class: 3
Identification No: UN1992
Packing group: II
Shipping name: Flammable liquid, toxic, n.o.s (Copper dispersion 15%, ethylene glycol 70%)

14. Regulatory Information

Classification and labeling: Research Chemical

R10 Flammable,
R20/21/22, Harmful by inhalation, in contact with skin and if swallowed
R50 Very toxic to aquatic organisms
R53 May cause long-term adverse effects in the aquatic environment
S7/8 Keep container tightly closed.
S29 Do not empty into drains
S43 In case of fire smother with sand or vermiculite or use Class D dry powder extinguisher. Do not use water.
S46 If swallowed, seek medical advice immediately

Other information

This safety information is provided in good faith and is based on the present state of our knowledge. However, we make no warranty of merchantability or any other warranty, expressed or implied, with respect to such information, and we assume no liability resulting from its use or misuse. Users should make their own investigations to determine the suitability of the information for their particular purposes. IML only obligation shall be to replace such quantities of material proved defective. Before using, the user, shall determine the suitability of the product for its intended use and the user assumes all risk and liability whatsoever in connection therewith. IML will not be liable for loss or damage, direct, incidental or consequential arising out of the use, or inability to use, the product.

Date of issue: March 2010

Issue Number 1.2

APPENDIX G
MSDS FOR SIGMA ALDRICH SILVER INK

Material Safety Data Sheet

Version 4.1
Revision Date 12/01/2010
Print Date 02/25/2011

1. PRODUCT AND COMPANY IDENTIFICATION

Product name : SILVER, DISPERSION, NANOPARTICLE, <=50 NM PARTICLE SIZE, 30-35 WT % IN TRIETHYLENE GLYCOL MONOETHYL ETHER, SPECIFIC RESISTIVITY ~7 U

Product Number : 736473
Brand : Aldrich
Product Use : For laboratory research purposes.

Supplier : Sigma-Aldrich
3050 Spruce Street
SAINT LOUIS MO 63103
USA

Manufacturer : Sigma-Aldrich Corporation
3050 Spruce St.
St. Louis, Missouri 63103
USA

Telephone : +18003255832
Fax : +18003255052
Emergency Phone # (For both supplier and manufacturer) : (314) 776-6555
Preparation Information : Sigma-Aldrich Corporation
Product Safety - Americas Region
1-800-521-8956

2. HAZARDS IDENTIFICATION

Emergency Overview

OSHA Hazards
No known OSHA hazards

Not a dangerous substance according to GHS.

HMIS Classification
Health hazard: 0
Flammability: 0
Physical hazards: 0

NFPA Rating
Health hazard: 0
Fire: 0
Reactivity Hazard: 0

Potential Health Effects

Inhalation May be harmful if inhaled. May cause respiratory tract irritation.
Skin May be harmful if absorbed through skin. May cause skin irritation.
Eyes May cause eye irritation.
Ingestion May be harmful if swallowed.

3. COMPOSITION/INFORMATION ON INGREDIENTS

Synonyms : Silverjet DGP-40TE-20C

Formula : Ag

CAS-No.	EC-No.	Index-No.	Concentration

Silver			
7440-22-4	231-131-3	-	>= 30 - <= 35 %
2-(2-(2-Ethoxyethoxy)ethoxy)ethanol			
112-50-5	203-978-9	-	>= 55 - <= 65 %
Non-hazardous components			
no data available	-	-	>= 5 - <= 10 %

4. FIRST AID MEASURES

If inhaled
If breathed in, move person into fresh air. If not breathing, give artificial respiration.

In case of skin contact
Wash off with soap and plenty of water.

In case of eye contact
Flush eyes with water as a precaution.

If swallowed
Never give anything by mouth to an unconscious person. Rinse mouth with water.

5. FIRE-FIGHTING MEASURES

Suitable extinguishing media
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

Special protective equipment for fire-fighters
Wear self contained breathing apparatus for fire fighting if necessary.

Hazardous combustion products
Hazardous decomposition products formed under fire conditions. - Silver/silver oxides

6. ACCIDENTAL RELEASE MEASURES

Personal precautions
Avoid breathing vapors, mist or gas.

Environmental precautions
Do not let product enter drains.

Methods and materials for containment and cleaning up
Keep in suitable, closed containers for disposal.

7. HANDLING AND STORAGE

Precautions for safe handling
Normal measures for preventive fire protection.

Conditions for safe storage
Keep container tightly closed in a dry and well-ventilated place. Containers which are opened must be carefully resealed and kept upright to prevent leakage.

Recommended storage temperature: 2 - 8 °C

Handle and store under inert gas. Do not freeze.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Components with workplace control parameters

Components	CAS-No.	Value	Control parameters	Update	Basis
Silver	7440-22-4	TWA	0.01 mg/m3	1993-06-30	USA. Occupational Exposure Limits (OSHA) - Table Z-1 Limits for Air

					Contaminants
		TWA	0.01 mg/m3	1989-03-01	USA. OSHA - TABLE Z-1 Limits for Air Contaminants - 1910.1000
		TWA	0.01 mg/m3	1997-08-04	USA. Occupational Exposure Limits (OSHA) - Table Z-1 Limits for Air Contaminants
		TWA	0.1 mg/m3	2008-01-01	USA. ACGIH Threshold Limit Values (TLV)
Remarks	Argyria				
		TWA	0.01 mg/m3	1989-01-19	USA. OSHA - TABLE Z-1 Limits for Air Contaminants - 1910.1000

Personal protective equipment

Respiratory protection
Respiratory protection not required. For nuisance exposures use type OV/AG (US) or type ABEK (EU EN 14387) respirator cartridges. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

Hand protection
Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Eye protection
Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

Skin and body protection
impervious clothing, The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

Hygiene measures
General industrial hygiene practice.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance

Form	liquid
Colour	no data available

Safety data

pH	no data available
Melting/freezing point	no data available
Boiling point	no data available
Flash point	no data available
Ignition temperature	no data available
Autoignition temperature	no data available
Lower explosion limit	no data available
Upper explosion limit	no data available
Vapour pressure	no data available
Density	no data available
Water solubility	no data available
Partition coefficient:	no data available

n-octanol/water	
Relative vapour density	no data available
Odour	no data available
Odour Threshold	no data available
Evaporation rate	no data available

10. STABILITY AND REACTIVITY

Chemical stability
Stable under recommended storage conditions.

Possibility of hazardous reactions
no data available

Conditions to avoid
no data available

Materials to avoid
no data available

Hazardous decomposition products
Hazardous decomposition products formed under fire conditions. - Silver/silver oxides

11. TOXICOLOGICAL INFORMATION

Acute toxicity

Oral LD50
no data available

Inhalation LC50
no data available

Dermal LD50
no data available

Other information on acute toxicity
no data available

Skin corrosion/irritation
no data available

Serious eye damage/eye irritation
Eyes: no data available

Respiratory or skin sensitization
no data available

Germ cell mutagenicity
no data available

Carcinogenicity

IARC:	No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.
ACGIH:	No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.
NTP:	No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.
OSHA:	No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity

no data available

Teratogenicity

no data available

Specific target organ toxicity - single exposure (Globally Harmonized System)
no data available

Specific target organ toxicity - repeated exposure (Globally Harmonized System)
no data available

Aspiration hazard
no data available

Potential health effects

Inhalation	May be harmful if inhaled. May cause respiratory tract irritation.
Ingestion	May be harmful if swallowed.
Skin	May be harmful if absorbed through skin. May cause skin irritation.
Eyes	May cause eye irritation.

Signs and Symptoms of Exposure
May cause argyria (a slate-gray or bluish discoloration of the skin and deep tissues due to the deposit of insoluble albuminate of silver).

Synergistic effects
no data available

Additional Information
RTECS: Not available

12. ECOLOGICAL INFORMATION

Toxicity

no data available

Persistence and degradability
no data available

Bioaccumulative potential
no data available

Mobility in soil
no data available

PBT and vPvB assessment
no data available

Other adverse effects

no data available

13. DISPOSAL CONSIDERATIONS

Product
Offer surplus and non-recyclable solutions to a licensed disposal company.

Contaminated packaging
Dispose of as unused product.

14. TRANSPORT INFORMATION

DOT (US)
Not dangerous goods

IMDG

UN-Number: 3082 Class: 9 Packing group: III EMS-No: F-A, S-F
Proper shipping name: ENVIRONMENTALLY HAZARDOUS SUBSTANCE, LIQUID, N.O.S.
Marine pollutant: Marine pollutant

IATA
UN-Number: 3082 Class: 9 Packing group: III
Proper shipping name: Environmentally hazardous substance, liquid, n.o.s.

Further information
EHS-Mark required (ADR 2.2.9.1.10, IMDG code 2.10.3) for single packagings and combination packagings containing inner packagings with Dangerous Goods > 5L for liquids or > 5kg for solids.

15. REGULATORY INFORMATION

OSHA Hazards
No known OSHA hazards

DSL Status
This product contains the following components that are not on the Canadian DSL nor NDSL lists.

	CAS-No.
Non-hazardous components	-

SARA 302 Components
SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
The following components are subject to reporting levels established by SARA Title III, Section 313:

	CAS-No.	Revision Date
Silver	7440-22-4	1993-04-24

SARA 311/312 Hazards
No SARA Hazards

Massachusetts Right To Know Components

	CAS-No.	Revision Date
Silver	7440-22-4	1993-04-24

Pennsylvania Right To Know Components

	CAS-No.	Revision Date
Silver	7440-22-4	1993-04-24
2-(2-(2-Ethoxyethoxy)ethoxy)ethanol	112-50-5	
Non-hazardous components	-	

New Jersey Right To Know Components

	CAS-No.	Revision Date
Silver	7440-22-4	1993-04-24
2-(2-(2-Ethoxyethoxy)ethoxy)ethanol	112-50-5	
Non-hazardous components	-	

California Prop. 65 Components
This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

16. OTHER INFORMATION

Further information

The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Co., shall not be held liable for any damage resulting from handling or from contact with the above product. See reverse side of invoice or packing slip for additional terms and conditions of sale.

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	Mr. Michael K. Gray michael.k.gray@us.army.mil	Electronic
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RDMR	C. Stephen Cornelius Steve.Cornelius@us.army.mil	Electronic
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